VOL. VII NO. 5

Engineering Library
GENERAL LIBRARY
NOV 8 1920
UNIV. OF CH.

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

NOVEMBER 1920

SOCIETY OF AUTOMOTIVE ENGINEERS INC.
29 WEST 39TH STREET NEW YORK

THE car owner buys a car for pleasure—not for the privilege of paying big repair bills for tear-downs on account of frequent bearing renewals due to use of inferior bearing material.

Non-Gran's tough and dense molecular structure makes Non-Gran resist shaft friction—wear slowly—keeping cars in service longer by putting bearing renewals further apart.

The Non-Gran booklets tell all about Non-Gran. May we send you copies?

AMERICAN BRONZE CORPORATION
BERWYN PENNSYLVANIA

District Offices

248 Tremont Bldg., Boston, Mass.
464 People's Gas Bldg., Chicago, Ill.
2010 Woolworth Bldg., New York, N. Y.
240 Leader-News Bldg., Cleveland, O.

District Offices

Pacific Coast Allied Industries, Inc.,
279 Minna St., San Francisco, Cal.
840 Azusa St., Los Angeles, Cal.
1252 1st Ave., So., Seattle, Wash.

THE UNIVERSAL
NON-GRAN
BEARING BRONZE

Foreign Distributors

Foreign Dept., Automotive Products Corporation, 2010 Woolworth Bldg., New York, N. Y.

Stanley J. Watson, Sheen Road, Richmond, London, England.

Aktiebolaget Gaico, 18 Norra Bantorget, Stockholm, Sweden.

Cycle Motor Trade Supply Co., Capetown and Durban.

Henderson & Co., Johannesburg, South Africa.

John O'Neill Pty., Ltd., Sydney, Australia.

Sucrs. de L. Villamil & Co., Porto Rico.

Simpon & Nielsen, Copenhagen, Denmark.

Havana Auto Co., Havana, Cuba.

Advance Motor Co., Bombay, India.

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. VII November, 1920 No. 5

Winter Meetings of the Society

PLANS for the coming Winter meetings of the Society are now well advanced. Great interest in the preliminary plans has been shown by a gratifying number of letters received from members making constructive suggestions of topics for discussion. The Meetings Committee wishes to encourage the submission of ideas as a certain means of making the technical sessions of maximum interest and value. The members are again urged to submit, in a competitive way, manuscripts on new and fundamentally important automotive engineering facts for possible presentation at the coming winter meetings.

Motor Boat Meeting

The Motor Boat Meeting will be held at the Automobile Club of America, New York City, Tuesday evening, Dec. 14, during the week of the national Motor Boat Show. The technical session will be preceded by an informal dinner at which Vice-President C. A. Criqui will act as toastmaster. The dinner speakers will be prominent members of the motor boat industry. The technical session will be devoted to the discussion of recent design advances in internal-combustion motor boat engines and the probable trend of their further development. Both the Otto and the Diesel cycles will be treated from the standpoint of economy, weight, accessibility and durability.

Annual Meeting

The Annual Meeting of the Society is scheduled to be held during the week of the New York Automobile Show, Jan. 11 to 13. The program of professional sessions at the Engineering Societies Building, New York City, which has been decided upon follows:

TUESDAY, JAN. 11

Morning and Afternoon—Standards Committee Meeting

WEDNESDAY, JAN. 12

Morning—Business Session

Afternoon—Body Engineering Session
Aeronautic Session

THURSDAY, JAN. 13

Morning—Fuel Research Session

Afternoon—Fuel Research Session
Highways Session
Chassis Session

During the fuel research session new and interesting chemical and physical phenomena of combustion will be disclosed. The Body Engineering Session will be devoted to the presentation of means to reduce body weight, a consideration of passenger-car body styles and a discussion of problems of construction. The Aeronautic Session will include a paper on the present status of commercial aviation in America and Europe, a study of recent developments in airplane design, and a discussion of the possibility of successful operation of commercial lighter-than-air craft. Because of the direct relation of the motor vehicle to the good-roads movement, it has been decided to devote one technical session to highways. It is planned to familiarize the members of the Society with the progress highway engineers are making with the problems of highway deterioration which were outlined at the Summer Meeting. The Chassis Session is intended to cover the relation of chassis design to fuel economy. This naturally raises the subjects of light weight, higher transmission and axle efficiencies and the reduction of rolling resistance.

Plans for the Annual Dinner at the Hotel Astor, Thursday, Jan. 13, are progressing under the direction of Chairman Azel Ames. The committee which is arranging a Carnival to rival that of last winter is headed by H. G. McComb. This social event will be held in the grand ballroom of the Hotel Astor on Wednesday evening, Jan. 12.

Chicago Meeting and Columbus Tractor Dinner

The Chicago Dinner will be held at the Hotel Morrison on the evening of Wednesday, Feb. 2. The morning and afternoon of the same day will be devoted to professional sessions with motor trucks as the principal topic.

The Annual Tractor Dinner will be given at the Hotel Deshler, Columbus, Ohio, on Thursday evening, Feb. 10. It is anticipated that many of the tractor engineers will be in Columbus during the National Tractor Show which begins Feb. 7, and that there may be a demand for professional sessions on tractor engineering on the day of the S. A. E. dinner. Expressions of the members on the desirability of holding such a technical program are solicited by the Meetings Committee.

The staff of the Society has ascertained the extent of probable hotel congestion during the automotive shows at the cities where meetings are scheduled, and the need for early placing of reservations cannot be too strongly emphasized.

SEPTEMBER COUNCIL MEETING

THE meeting of the Council held on Sept. 25 was attended by President Vincent, Past-President Manly, Vice-Presidents C. A. Ctiqui and G. L. Martin, Councilors Fergusson and Pope and Chairman Beecroft of the Meetings Committee.

The place and date of various coming meetings of the Society, as announced in this and the October number of THE JOURNAL, were decided upon.

STANDARDS COMMITTEE

The following new subjects were assigned to Standards Committee Divisions:

Shaft Length of Through-Drive Generators—Electrical Equipment Division
Mufflers—Engine Division
Passenger-Car Frames—Frames Division
Molybdenum Steels—Iron and Steel Division
Lubricants—Lubricants Division
Felt Specification—Miscellaneous Division
Taper Pipe-Threads—Miscellaneous Division
Cast-Iron Radiators—Radiator Division
Pneumatic-Tire Metric Sizes (For Export Only)—Tire and Rim Division
Solid-Tire Metric Sizes (For Export Only)—Tire and Rim Division
Split-Rim Mountings—Tire and Rim Division
Passenger-Car Radiators—Radiator Division
Electrical Equipment Nomenclature—Electrical Equipment Division
Automobile Wiring—Electrical Equipment Division
Carbureter Intakes—Engine Division
Clutch Facing—Transmission Division

The following additional appointments to the Standards Committee were made with assignment as indicated:

Prof. G. B. Upton—Lubricants Division
Dr. W. H. Herschel—Lubricants Division
C. T. Myers—Truck Subdivision on Wheels
F. C. Barton—Isolated Electric Lighting Division
C. E. Jeffers—Frames Division
C. L. Wood—Frames Division
J. A. Kraus—Frames Division
A. J. Scaife—Committee on Schedule of Automobile Hazards
A. K. Brumbaugh—Committee on Schedule of Automobile Hazards
F. G. Hughes—Ball and Roller Bearings Division
G. C. Mather—Sectional Committee on Gears of American Engineering Standards Committee

The Council directed that in accordance with the request of the American Engineering Standards Committee the Society should act as joint sponsor with the Bureau of Standards in the organization of a Sectional Committee on an Aircraft Safety Code.

FINANCIAL MATTERS

A financial budget for the current fiscal year was adopted, the contemplated income basis being somewhat in excess of $300,000. Among the items of expense to which income was distributed were: Publications, $110,500; Standards, $35,500; Meetings, $15,000; Sections, $14,000; General Administration, $104,500.

The income of the Society for the fiscal year ended Sept. 30 last was in excess of expenditures for the corresponding period. The net expense for 11 months of the fiscal year was more than $27,000 less than was contemplated in the budget.

MEMBERSHIP

Three hundred and three applications were approved, 122 for Member, 2 for Foreign Member, 2 for Service Member, 102 for Associate, 64 for Junior and 4 for Affiliate grade of membership, 2 for Affiliate membership representation and 5 for Student Enrollment.

H. A. Coffin, A. H. Miller, William Owens, G. W. Pierce, J. S. Schneider, H. I. Stengel and A. L. Vargha were transferred from Associate to Member grade; and R. S. Barnaby from Junior to Member grade.

The resignations of the following as members of the Society were accepted: J. E. Crane, H. L. Davisson, R. M. Skillman, M. M. Whitaker, A. E. Eldredge, D. H. Elkins, H. J. Leab, John Van Nortwick, W. E. Whipp and H. C. White.

One hundred and four applications for membership were received in August of this year, as compared with 25 for the same month of 1919. On Sept. 9 there were 4823 individual and affiliate members on the rolls of the Society, and in addition 171 affiliate member representatives and enrolled students. Thirty-nine student enrollments have been concluded recently, the men having been enrolled for the full period of 3 years authorized by the Constitution of the Society. On Sept. 9 last the roster of the Society aggregated 701 more than on the same day of last year. This figure represents approximately the net increase in membership of the Society for the period. About 400 applications for membership have been received since June 1, at least 20 per cent of these having been due to the Factory Representative Membership Increase Plan of the Membership Committee. Over 200 applications for membership in the various Sections of the Society have been received at the New York office recently.

MISCELLANEOUS MATTERS

A communication received from the National Implement & Vehicle Association on the subject of Standard Wagon Track and Steel Tire Widths was referred to the Motor Vehicle Conference Committee.

President Vincent announced the appointment of G. W. Vaughan as a member of the Publication Committee of the Society, to succeed Prof. H. C. Sadler.

Henry M. Crane was designated as the representative of the Society on the Power Plant Committee of the National Advisory Committee for Aeronautics.

It was decided that the Society would appoint a representative on the Sectional Committee on Safety Code for the Use of Grinding Wheels, the joint sponsors of this committee being the International Association of Industrial Accident Boards and Commissions, and the Grinding Wheel Manufacturers' Association of the United States and Canada.

Past-President Kettering was named as the representative of the Society and recommended as the spokesman of the automotive industry at the annual meeting of the American Petroleum Institute to be held in Washington on Nov. 18.

PHILIPPINE IRON ORE DEPOSITS

ACCORDING to a report of Government experts received by the Bureau of Foreign and Domestic Commerce, the finest unworked iron ore deposits in the world have been discovered in the Philippine Islands. It is stated that there are great quantities of ore adjacent to good harbors.

PROPORTION OF URBAN POPULATION

BUREAU of Census statistics show that more than one-fourth of the people of the United States live in cities which have a population of 100,000 or more, and that one-tenth of the entire population resides in New York, Chicago and Philadelphia.

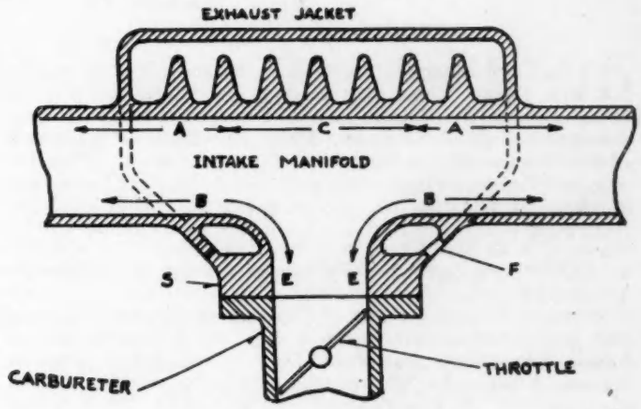
Localizing Heat in Inlet Manifold

H. L. HORNING, chairman of the Fuel Committee, whose report on the application of heat to assist in securing increased engine efficiency was presented at the Summer Meeting of the Society, in a letter written recently says

> There is one point in the Bureau of Standards tests that disagrees, at least in degree, with the S. A. E. Fuel Committee Report and I feel this matter should not pass without some notice. I did not accept fully the visual demonstration of the Bureau of Standards tests as conclusive evidence of the location of the best point of application of heat to the manifold for maximum vaporization. Putting it another way, I am not satisfied that localizing exhaust or any other flame at the points which seem to carry the most fuel would result in the maximum vaporization, which after all is our objective.
>
> Granting that the Pyrex shows the maximum deposit at *B* in the accompanying illustration which was Fig. 1 in the report, it seems more than probable that heating along the surface *C* would reduce the deposit at *B* more than if the heat were concentrated at *B*. This is because the liquid at *C* is thinner and more easily heated than at a place where it is in greater mass. But if the heat is applied most intensely at *C*, the thickness of the liquid at *B* may be made much less than if the heat were concentrated at *B*.
>
> Deductions made from observations with glass manifolds may lead to error, because of the low heat conductivity of the glass. A metal manifold with heat applied only at *C* will be very hot indeed at *B*; that is, there will be relatively little difference in temperature between the manifold surface at *C* and at *B*. With glass there will be a much wider difference in the temperature.

W. S. James, who reported at the meeting of the Society in June on the above mentioned Bureau of Standards tests, makes the following statement.

> A discrepancy has been pointed out between the S. A. E. Fuel Committee Report and the results of the tests made at the Bureau of Standards as noted in the footnote on page 5 of the Society's pamphlet entitled Data Pertaining to the Internal-Combustion Engine Fuel Problem, and by Mr. Horning in a written discussion of the results of the Bureau's work. The discrepancy appears to rise from a confusion between the location in the intake manifold of the points where the maximum quality of fuel *collects* and where the maximum quantity of fuel can be *vaporized* by the application of heat. As pointed out in the Bureau's report of its work published in the August issue of THE JOURNAL, page 132, under the heading of Preliminary Tests, the maximum quantity of fuel collects at the bottom of the horizontal portion of the manifold or points *BB* of the Fuel Committee's Report and the maximum quantity of fuel can be vaporized by the application of heat at the top of the manifold above the carbureter outlet or at points *C* and *A* of the Fuel Committee's Report. When the entire tee of the glass manifold was heated almost to a dull red, liquid still collected on the lower horizontal portion of the manifold, although in smaller amounts than when the tee was unheated. This liquid was observed to come from the inside surface of the vertical section of the tee and, as noted in the Bureau's report (See page 133 of August issue of THE JOURNAL) was eliminated by heating the vertical section of the manifold below the tee.



HEATED-SURFACE MANIFOLD

The importance of the study of the liquid collecting on the walls of an intake manifold, whether heated or not, should be pointed out. The work at the Bureau of Standards showed that when an engine was running at a relatively low speed, say 650 r.p.m., more liquid was present on the walls at full load than when idling. What will happen when the throttle is opened suddenly with the engine idling is obvious. A portion of the fuel leaving the carbureter will be deposited on the walls, the remainder entering the cylinders. When the wall layer is in equilibrium with the velocity of mixture flow, all of the fuel leaving the carbureter will enter the cylinder. The quantity of fuel required to establish this equilibrium condition is not constant for all engine speeds and with all manifold designs and therefore cannot be supplied from an "accelerating well" without loss of economy. The real solution of the problem would be to maintain the quantity of liquid fuel present on the inside of the intake manifold walls as nearly constant as possible at all speeds and loads; the ideal condition being a dry wall. Maximum brake mean effective pressure cannot be attained with such a condition, however, and the resulting compromise between brake power and economical rapid acceleration seems to be the hot spot.

The one most obvious conclusion to be drawn from the results of the tests at the Bureau of Standards seems to have been overlooked in the discussion and it is advantageous to direct attention to it. The results show clearly that carbureter and manifold performance is markedly different when an engine is accelerating under an inertia and friction load and when running at a constant speed and under a constant load. A study of the great mass of data now available on engine performance will reveal very meager if any reliable information on engine operation and economy under changing loads and speeds. This is true in spite of the fact that a least 75 per cent of the car mileage in this country is made under changing speeds. A plea is therefore made for a closer study of engine performance and requirements when accelerating under car loads.

NEW YORK STATE'S BARGE CANAL

GREAT consequences followed from the building of the Erie Canal. There was made in the wilderness a great inland empire, the Empire State. There were tapped the resources of a vast hinterland. There was made at the mouth of the Hudson the metropolis of the new nation. Philadelphia lost its commercial supremacy when the Erie Canal was finished. It was not the bellying sails of argosies from the seven seas that made New York the metropolis of the United States and of the North American continent. It was the snub-nosed Erie Canal boats drawn at the end of towlines by horses and mules.

As trade follows the line of least resistance, the railroads that got the water level route held a preponderating power. It was not accident that placed the first railroad in America between Albany and Schenectady: it was the everlasting call of commerce. It was not accident that drew the different short lines finally into the New York Central system: it was the water level route into the interior of a rich inland empire. Nor was it accident that dictated the construction of the Barge Canal, the most wonderful inland waterway in the world: it was merely the beginning of another chapter in the romance of the route the waters carved, another event in the destiny of the great inland empire. This is why this rivalry between the Barge Canal and the St. Lawrence for the golden harvest of our plains is the most natural thing in the world.

In its latest phase, the waterway through the route which nature carved with great travail follows the old water course of 30,000 years ago. Whereas the Erie Canal was a man-made ditch, clinging for a big share of its way to the hillsides along the Mohawk, and crossing that river on several laboriously constructed and wonderful aqueducts, the Barge Canal uses lakes and rivers about three-quarters of its length. By the use of two great masonry dams and eight movable dams, the Mohawk River has been made a series of navigable pools. It was most exquisite engineering to build this canal, and engineering never had greater triumph. For, in addition to the technical difficulties to overcome, there was the ever-present difficulty of the vested interests along the route which had to be protected every foot of the way. Cities and villages are numerous. Farm lands must not be flooded. Construction work had to be shaped, not with the single idea of getting the work done, but with the added idea of not doing damage.

The movable dam device itself is a wonderful adaptation to circumstances. The Mohawk is subject to spring freshets: therefore no dam must obstruct it in the spring. It was too shallow to navigate: therefore dams must be built. Practically these movable dams are nothing more than substantial steel bridges, from which flashboards can be suspended in the water to make a dam. A lock permits boats to go around the dam.

The Erie Canal section of the Barge Canal system is 340 miles long. There are other sections that make the State's total deep inland waterways 444 miles. The Barge Canal is 200 ft. wide in lakes and rivers, 94 ft. wide at the bottom in rock cuts, and 75 ft. wide at the bottom in land cuts. A uniform depth of 12 ft. is maintained, which permits boats of 9 ft. draft to navigate. There is a 15½-ft. clearance between the top of the water and the overhead structures. There are 35 locks in the Erie division. The highest-lift lock of its sort in the world is at Little Falls, lifting boats 41½ ft. Each lock is 310 ft. long and 45 ft. wide. The lock gates are moved by electric power, generated by the water as it passes through the lock.

The most wonderful flight of locks in the world is at Waterford, where the series of five enormous concrete structures lifts boats 169 ft., twice the height of all the locks of the Panama Canal, as it takes them up out of the Hudson valley and places them on the level of the Mohawk River before the Mohawk tumbles over the Great Falls which are about 180 ft. high at Cohoes.

One man can lock a fleet of four boats through a couple of these modern locks, pushing a lever with his foot and manipulating certain electric switches with his hands. The potential carrying power of this wonderful waterway which the State of New York has constructed at a cost of $155,000,000 is practically limitless. There is no limit to it except the locking capacity. As fast as locks can empty and fill, boats can be sent through. To make a definite figure, an estimate of 10,000,000 tons a year is set. That means a year based on the length of the period of navigation which is seven months on the average.

The canal was calculated to take a standard barge of 300-ft. length, 42-ft. beam and a draft of 9 to 9½ ft. Such a boat could carry 2800 tons, the equivalent of about 93 freight cars. And in that estimate we get a line on the railroad hostility to water commerce. Although, through that neck-of-the-bottle at Little Falls, freight trains mill their way with discretion, although the freight traffic at times clogs the railroads, there is suspicion of well-founded opposition on the part of railroad interests to canal traffic. When one barge can carry as much as 93 freight cars at a much lower freight rate, one can see the advantages in canal commerce.

There is still another factor, that of the original investment. The cost of a 2800-ton barge might be $50,000. These estimates were given to me before the prevailing increase of prices. A 100-car freight train could not cost less than $180,000. An engine to haul it could not cost less than $50,000, making a total investment for a railroad of $230,000 to haul what one barge can carry. Still another factor is the operating cost. The freight train has a highly specialized crew of half a dozen men working say, 8 hours a day. A barge would have two men, possibly, besides the skipper, and the nature of the traffic makes it possible for these men to relieve one another to the end that a few men in shifts can navigate long stretches of water. But, if traffic conditions show that a fleet of four boats is better than one big boat, such a unit would be made up of one propeller and three freight carriers, each being 150 ft. long, 21 ft. wide and of 8 or 9-ft. draft. Carrying a total of about 2500 tons, such a unit would do the work of a train of 83 freight cars, each with a capacity of 60,000 lb. Here is the crux of rail opposition to water: the cheaper equipment and cheaper operation which would make enormous cuts in transportation charges. It would make competition keener than rail routes desire. The sort of freights in which the water route would excel is bulk freights of materials like ore, grain and coal.

Grain ought to afford 70 per cent of the eastbound freight on the Barge Canal. In the year 1880, the old Erie Canal carried 30,000,000 bu. of wheat from Buffalo, and 10,000 boats and more were in the business. In 1919 there were only 400 boats carrying wheat, and the total freight of this sort was only 500,000 bu. Domination of elevator and terminal facilities by railroad interests accounts for much of this decadence. At the port of New York there are but five or six grain elevators. Only two of them are situated so as to receive canal-borne grain, and both are operated by railroads competing with the canal route for grain freight. Of the 23 grain elevators at Buffalo, it is generally understood that some, if not all, are dominated by railroad interests. However, it might be possible to get grain cargoes at Buffalo if it were possible for canal boats to discharge them at New York. Cargoes now are at the mercy of chance and the railroads, and many canal boats have been obliged to tie up in New York harbor for days before they could discharge their loads, thus adding to the freight costs.—Walter H. Main in *Transportation World.*

Air Navigation

By E. S. Gorrell[1] Semi-Annual Meeting Paper

PRESIDENT VINCENT has called attention to the necessity of building an industry around the airplane, the most rapid and newest means of transportation. The airplane provides a form of transportation wherein the slowest speed is now about 60 m.p.h. Express airplanes certainly will travel at more than 300 m.p.h. I believe that the airplane is worthy of a place, along with the horse and the truck.

To build an industry around the airplane, three things are essential. First, we must have better engines. I mean by that, more reliable engines, engines which can be actually depended upon. When it is necessary to come down within 10 ft. of the ground or to skim the housetops, one must be certain that the engine will not fail. If it is necessary to go above the clouds, out of sight of the earth, one must be certain that the engine is reliable. That is essential if people are to travel frequently by airplane. Automotive engineers are competent to make aircraft engines reliable and the aircraft industry looks to them to do it.

The next point is the development of the airplane. We look to you to help design better airplanes. Given a better airplane and a much better and more reliable engine, commercial aeronautics will become an accomplished fact.

There is one other phase. We need instruments that will allow us to fly in any kind of weather and find the destination sought, and enable us to land in safety when we arrive at that destination. I believe that we can design and construct such instruments.

Ever since the Wright brothers made their first flight at Kitty Hawk, there have been men who visualized that commercial aeronautics would some day arrive. By commercial aeronautics I mean that form of civil and commercial endeavor which will show a profit when the books are audited. Those of us engaged in aeronautics before and during the war figured that it would be a long time before commercial aeronautics would pay for itself; then came the war and aircraft development went forward rapidly. With the devices brought out since the war, we are almost on the verge of commercial aeronautics. I think it will not be long before we shall see aeronautics at the point where it will pay for itself.

Rules of the Air

The rules of the air are based on the International Convention on Air Navigation formulated at Paris last year. International conventions, when adopted by a country, have the same status as treaties. They are the supreme law of the land. All national laws and regulations must conform to them.

Shortly before the end of the war, all combatant nations had trained thousands of men in aeronautics, as flyers, mechanics and engineers. They had large buildings, factories, aircraft engines and accessories. The warring nations realized that they were pouring out money very rapidly to support the aircraft industry. We appropriated about $1,600,000,000 for aeronautics. We spent a large portion of this, and many condemned us for doing so. Before we went into the war, we received a cablegram from England saying that it would cost us $1,000,000,000 to place our first 1000 flyers upon the lines. We sent over twice that number to the front. The problem faced the nations as to what should be done with this industry that was built up during the war. Were they to let it go to pieces and, when another war occurred, spend the necessary time and money to build up another; or, were they to preserve it in some way? Every nation realized that it could not maintain, in time of peace, air fleets sufficient for any modern war. The only way to be prepared for a modern war was, and is, to put aeronautics upon a basis on which it will pay its own way. Then, when war does break out, aeronautics can be mobilized. Of all nations among the Allies, Great Britain was far in the lead in sensing the future of aircraft. About a year before the armistice the British convened a board composed of a large number of civilians proficient in aeronautics and of their best available aircraft officers. This board at the end of a year's work presented a most elaborate report, very detailed from the scientific point of view, covering the financial phases and in general giving a comprehensive statement on the possibility of commercial aeronautics.

About January, 1919, at the instigation of a member of the French Chamber of Deputies, M. Clemenceau invited the United States, Great Britain, Italy, Japan and five of the small allied powers to meet through representatives for the purpose of drafting an International Convention on Air Navigation. Due to certain political causes, although delegates from the United States and several other countries were appointed, the meeting contemplated was never held. However, a few weeks after the time for the holding of that convention, another message from M. Clemenceau suggested the same idea but from a different angle. That resulted in the plan to draft a convention to be adopted by all allied countries and therefore become the treaty between those countries on aerial navigation. Shortly after the first meeting the delegates from some of the European nations thought that they did not have sufficient power. Consequently they took certain action which resulted in the creation at one of the sessions of the Supreme Council of the Peace Conference, of an aeronautical advisory board or body to the Peace Conference. This body was identical with the International Convention on Air Navigation. Consequently, this convention assembled for aerial navigation purposes, had assigned to it the duty of advising the Peace Conference upon aeronautical questions. The labors of this convention resulted in what appears in the Peace Treaty in the form of the aeronautical terms imposed upon the enemy.

On April 9, 1919, this International Convention met and laid down 12 fundamental principles by which all nations were to be guided in navigating the air. This laying down of the 12 fundamentals took place in less than one morning. I mention this because in 1910 there had been an International Aeronautical Convention which convened in Paris, sat for a long time and came to no

[1]M. S. A. E.—Sales extension engineer, Nordyke & Marmon Co., Indianapolis; formerly colonel in the Air Service.

decision because none of the vital points could be agreed upon. This indicates the advance of thought among all nations between 1910 and 1919.

The fundamentals having been determined upon, three sub-committees were formed; one legal, another technical and the third military. They began work, drafted a proposed convention and placed it before the main body. The main body consisted of delegates from the United States, Great Britain, France, Japan and Italy. Also, it was at first supposed to include a representative from each of five small countries, but that number was finally increased to seven. The reason for this was that Mr. Balfour believed Portugal should be represented because the Azores were important. Mr. Lansing said that if Portugal were represented, Cuba also ought to be represented. Someone asked why he wanted Cuba represented. Mr. Lansing said, "Who furnished the sugar during the war?" That is the way Cuba became represented. Thus, 12 nations had direct representatives around the table. As a matter of fact, they represented 23 nations. They decided upon the International Convention which I think is fundamentally sound and should be adopted by all countries. If any country, for example the United States, is not disposed to adopt internationally the regulations and the proposed laws found therein, they will serve in large part for its national law.

Subjects Considered by International Convention

It became evident at once that there were two classes of subjects that had to be considered. One comprised the vital points which the law-making bodies of each country had to ratify with or without modification. The other included technical matters which should be changed as the science of aeronautics progresses. The convention was thus divided into two parts. One part included the "Articles," which cannot be changed except by the law-making bodies of each country; the other, the "Annexes" or technical part, which can be changed easily when necessary to keep pace with the progress of aeronautics.

The first article of the convention states that each and every nation recognizes that every nation has exclusive sovereignty in the air space above its territory and territorial waters. That was the stumbling block in the convention of 1910. The Germans demanded that the air above 3000-ft. altitude should be internationalized, just as the oceans are internationalized beyond 3 miles from the shore. As we look back upon the war, it is not hard to divine that Germany may have had in mind a war such as actually occurred. She may have desired to fly across any country above 3000 ft., turn bombs loose and wage aerial warfare from the high seas, so to speak.

The next point was freedom of passage. Everything possible has been done to the end that an aircraft may get up from its home airdrome and with certain exceptions fly along any line it desires, taking the shortest route to its destination. If that were not possible the airplane would not be feasible commercially from an international point of view. The sole function of the airplane is the saving of time. There are some limitations upon the routes that may be followed. Aircraft may not cross what have been called prohibited zones. We do not want Canadian, Mexican or other foreign aviators flying over our arsenals and photographing them, thereby securing sufficient information to enable them to blow them up in time of war. We do not want them to fly across the Panama Canal and photograph the locks. Any nation may stipulate whatever prohibited zones it desires for its own protection, notifying the other nations what these are.

The convention contemplates certain minimum requirements with reference to an aircraft being airworthy. That is to protect human life when conveyed in aircraft. There are to be rules for the efficiency of the pilots, wireless men and members of the crew. That also is to protect human life. What shall and shall not be carried has been outlined; for instance, arms and munitions of war may not be carried in international air navigation; also, each nation has the right to say whether its own aircraft shall carry cameras; if its own aircraft do not carry cameras, it can forbid the aircraft of other nations to carry them.

If burglary is committed in a craft flying across France, what law applies? The convention gives the answer. Another thing is important to everyone. The convention stipulates that every dispute shall be settled by arbitration.

The technical appendices of the convention deal with the markings of aircraft, wireless signals while in flight, the ways in which landings shall and shall not be made within an airdrome, the markings of signals upon the ground and various matters that will change from time to time as the science progresses. An International Commission on Air Navigation has been created as a permanent body to sit, first of all, in Paris. It will probably have its permanent seat at the headquarters of the League of Nations, if there be such a body. The permanent commission is to be a clearing house of information; just as one automobile manufacturer passes on his thoughts to another through the S. A. E., so will one nation pass on its thoughts to another nation through this commission. The object is to speed up aeronautical development and establish commercial aeronautics as rapidly as possible.

It might be asked whether, if all the nations are to have a vote and, let us say, Madagascar and a few other small countries should outvote the United States, we shall be required to live up to the decision. Each small power has one vote. The total number of countries represented in the convention, divided by five, gives the number of votes allotted to each of the five large countries.

There are several bills before Congress now on the subject of regulating aeronautics. Everyone should take an interest in them. As scientists, as engineers, we should look carefully into them, in order that commercial aeronautics shall not be ruined by them. The best of all the bills now before Congress, and one which I think is drawn along correct lines, is what is known as the Moran Bill. Any bill along its general lines is satisfactory. The fundamentals which automotive engineers must insist that Congress follow are these: First, any legislation that is passed must not deprive the Army and the Navy of their air forces. The Army must keep its air force; the Navy must keep its air force. Next, there must be created a non-executive department of aeronautics or some other kind of a body of aeronautics within the Government to handle questions of commercial aeronautics. The Director of Aeronautics, or whatever the chief's title shall be, must have the right to regulate aeronautics broadly in order that he can change the regulations whenever necessary, so that there will be no unjust handicap to the use of aircraft. It is essential that every person give assistance of some kind to the aircraft industry. Commercial aeronautics cannot be born of itself. It cannot be born unless every man helps to design better engines. When thinking of more reliable engines and fuel economy for automobiles, try to think also of the necessities for commercial aeronautics.

Torsional Vibration and Critical Speeds in Crankshafts

By J. F. Fox[1]

METROPOLITAN SECTION PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

IT has long been recognized that, in the case of automotive engines and particularly those of six or more cylinders, excessive vibration is apt to occur despite all precautions taken in balancing. It is also generally recognized that this vibration is due to the fact that the engine impulses coincide at certain speeds with the torsional period of the crankshaft; that is, with the rate at which the crankshaft naturally twists and untwists about some point or points in its length as nodes. In the case of small engines, vibration of this character is usually avoided by the use of crankshafts much larger than the calculations ordinarily employed call for.

In the main engines for the 800-ton United States submarines S4 to S9, very serious vibration was found to occur at the normal maximum speed. These engines are of the four-cycle Diesel type, with eight working cylinders and two air-compressor cylinders all in line; ten cylinders in all. The air-compressor cylinders are forward of the working cylinders. These engines are coupled at their after end to the main propelling motor generators by a multiple-toothed jaw clutch. Aft of the propelling motors is another jaw clutch, by which the propeller-shaft can be disconnected and the engine used to drive the motor generator alone when charging batteries. Fig. 1 shows the arrangement of shafting.

[1]M. S. A. E.—Draftsman in charge of oil-engine work, New York Navy Yard, Brooklyn, N. Y.

Fig. 2 shows the engine mounted on the shop test-stand. The arrangement of shafting is the same as in Fig. 1 except that all the shafting aft of the motor generator is omitted, including the propeller clutch.

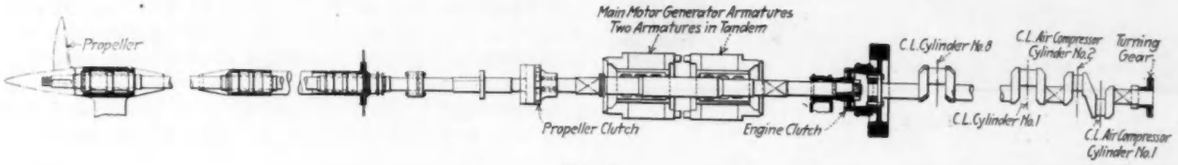


FIG. 1

The engines are required by the specifications to complete the following non-stop shop tests:

(1) A 2-hr. test at 350 b.hp. and 250 r.p.m.
(2) A 2-hr. test at 525 b.hp. and 300 r.p.m.
(3) A 2-hr. test at 150 b.hp. and 325 r.p.m., followed by a governor test
(4) A 2-hr. backing test at 525 b.hp. and not over 350 r.p.m.
(5) A 24-hr. test at 700 b.hp. and 350 r.p.m. except that, for two consecutive hours at some time between the sixth and eighteenth hours, the engine is required to develop 770 b.hp. at 370 r.p.m.

When the first engine was placed on the test-stand, no difficulty was experienced in completing the first four tests. Upon attempting a preliminary run at 700 b.hp. and 350 r.p.m., very serious vibration, starting at about 330 r.p.m., took place for the first time. This vibration was particularly violent at the forward or air-compressor end of the engine. Working cylinder No. 8 at the after end of the engine also vibrated badly, rebounding over 1/32 in. on the housing with each power stroke. After running 30 min. the engine was stopped and an unsuccessful attempt made to disengage the clutch. Inves-

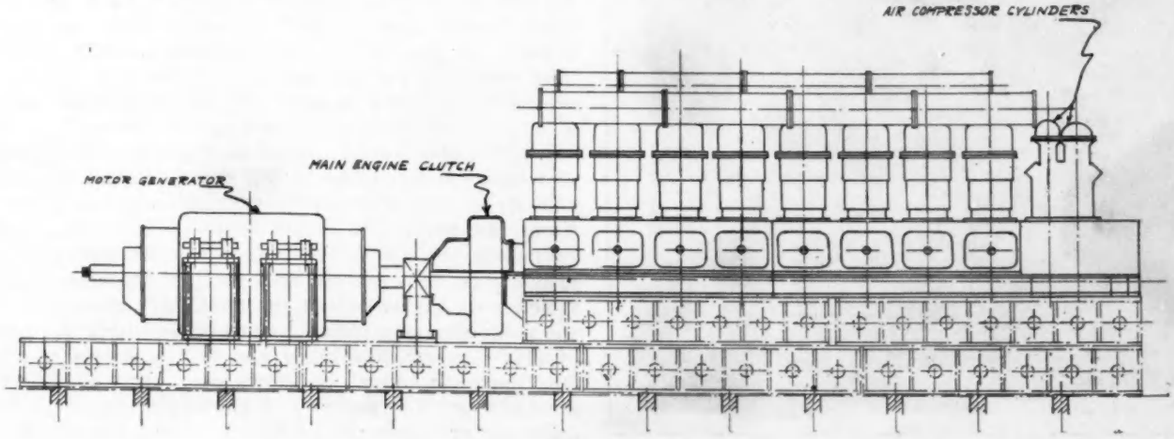


FIG. 2

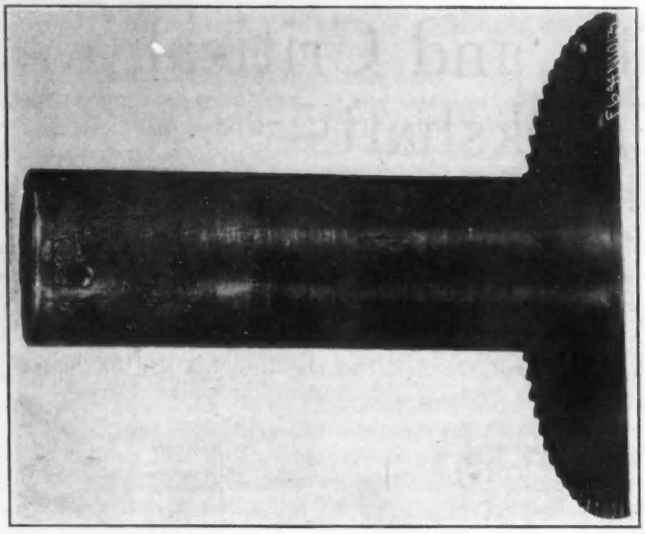


FIG. 3

tigation showed the clutch to be very hot. After cooling over night the clutch was disengaged easily. Repeated attempts to run test (5) were made without success, the hub of the clutch member attached to the motor-generator shaft becoming almost red-hot on one occasion. Increasing the clearance of the clutch teeth from 0.005 to 0.010 in. was tried without success, in an effort to prevent overheating. The last attempt to run at 350 r.p.m. resulted in shearing the teeth of the spray camshaft driving gears, after running about 1½ hr. These gears are driven from the forward end of the engine crankshaft.

The appearance of the camshaft after removing these gears is shown in Fig. 3. After this casualty it was seen that it was impossible to complete a run at 350 r.p.m. A 24-hr. run was finally completed at 365 r.p.m. At this speed vibration was still violent and it was necessary to keep two lines of ⅜-in. air-hose playing constantly on the motor end of the clutch to prevent overheating. Some time after running this test an attempt was made to remove the main engine clutch hub from the generator. A pressure of 90 tons failed to remove this hub and it was finally necessary to split it from the shaft. Its appearance is shown in Fig. 4 and that of the end of the motor shaft in Fig. 5. The bolts securing the forward clutch member and flywheel to the crankshaft are shown in Fig. 6.

FIG. 4

TUNING-FORK TORSIONAL-VIBRATION STUDY

Upon disassembling the engine for post-trial examination the crankshaft was found badly cracked in bearings Nos. 8, 9 and 10 and in crankpins Nos. 7 and 8. From the action of the engine it was concluded that the difficulties encountered were due to torsional vibration, and that the node of this vibration was located at some point in the vicinity of the main engine clutch. To demonstrate this the following method was used: Upon the turning gear at the forward, or free, end of the crankshaft, a brass plate coated with lamp-black and oil was mounted. The position of the turning gear is shown in Fig. 1. The engine was then run at its critical speed of 350 r.p.m. and a vibrating tuning-fork with a thin brass reed attached to one prong drawn horizontally across this plate. The result of this experiment is shown in Fig. 7.

FIG. 5

Inspection of the diagram traced on the plate by the tuning-fork reveals that it consists of a spiral line made up of a series of waves and that the angular distance between successive waves is not constant; that is, some of the waves are bunched together while others are spread wide apart. Had the shaft been moving uniformly, the angular distance between waves would have been constant, for the reason that the rate of vibration of the tuning-fork is constant and independent of variations in the angular velocity of the crankshaft. Further inspection shows four sets of closely-spaced and four sets of widely-spaced waves in 360 deg.; that is, the angular velocity of the crankshaft increases and decreases four times per revolution. This is to be expected, as eight four-cycle cylinders give four power impulses per revolution. To demonstrate still further the amplitude and violence of the variation in crankshaft speed shown on the polar diagram traced by the tuning-fork, an analysis of this diagram was made and this is shown in Fig. 8. One complete spiral is shown and upon it have been marked: (*a*) The position of the engine cranks, (*b*) the positions of maximum crank effort and (*c*) the angular distance between successive waves for one revolution of

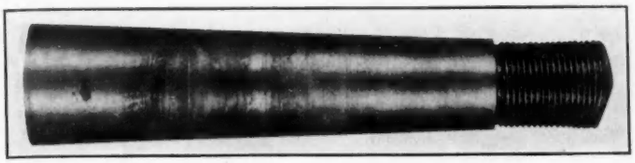


FIG. 6

forward end of the crankshaft for an elapsed time t. From this curve it is seen that in 0.172 sec. the shaft has passed through 360 deg., while in 0.085 sec. it has passed through slightly less than 180 deg. The first differential of this curve or its slope at any point, $\frac{d\theta}{dt}$, is therefore the velocity in degrees per 0.010 sec. Curve c is obtained by taking this first differential for a number

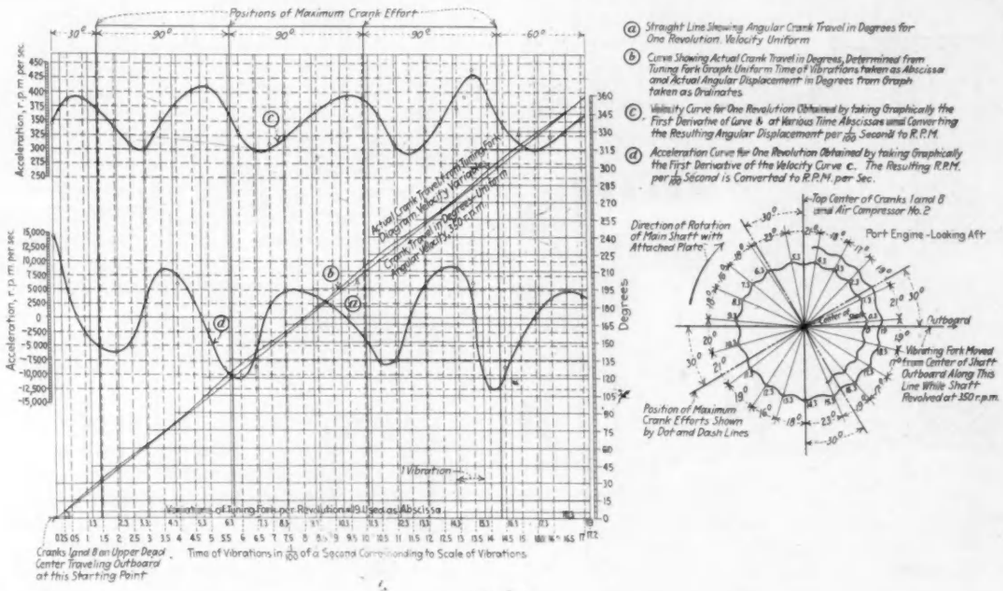

Positions of Maximum Crank Effort
-30°
-90°
-90°
-90°
-60°
Acceleration, r.p.m. per sec.
Degrees
Actual Crank Travel from Tuning Fork Diagram, Velocity Variable
Crank Travel in Degrees, Uniform Angular Velocity, 350 r.p.m.
Vibration
Variations of Tuning Fork per Revolution=19 Used as Abscissa
Cranks 1 and 8 on Upper Dead Center Traveling Outboard at this Starting Point
Time of Vibrations in 1/100 of a Second Corresponding to Scale of Vibrations
(a) Straight Line Showing Angular Crank Travel in Degrees for One Revolution, Velocity Uniform
(b) Curve Showing Actual Crank Travel in Degrees, Determined from Tuning Fork Graph, Uniform Time of Vibrations taken as Abscissae and Actual Angular Displacement in Degrees from Graph taken as Ordinates
(c) Velocity Curve for One Revolution Obtained by taking Graphically the First Derivative of Curve b at Various Time Abscissas and Converting the Resulting Angular Displacement per 1/100 Second to R.P.M.
(d) Acceleration Curve for One Revolution Obtained by taking Graphically the First Derivative of the Velocity Curve c. The Resulting R.P.M. per 1/100 Second is Converted to R.P.M. per Sec.
Top Center of Cranks 1 and 8 and Air Compressor No. 2
Direction of Rotation of Main Shaft with Attached Plate
Port Engine - Looking Aft
Outboard
Vibrating Fork Moved from Center of Shaft Outboard Along This Line While Shaft Revolved at 350 r.p.m.
Position of Maximum Crank Efforts Shown by Dot and Dash Lines

FIG. 8

the crankshaft. There are 19 vibrations of the tuning-fork to one revolution of the crankshaft. Plotting vibrations of the tuning-fork as abscissas and degrees of travel as ordinates, curve b in Fig. 8 results. The straight line a represents what would have resulted had the shaft moved uniformly. The vertical distance between the straight line a and the curve b is the amplitude of the vibration at the forward end of the crankshaft, in this case about 5 deg.

The curve b is a curve of degrees traveled by the

ROTATION OF SHAFT, 350 R.P.M.
CENTER OF SHAFT
Outboard →
Frequency of Tuning Fork 111 Vibrations per Second, Moving from Center of Shaft Outboard Along This Line
Order of Firing:
1-6-2-4-8-3-7-5

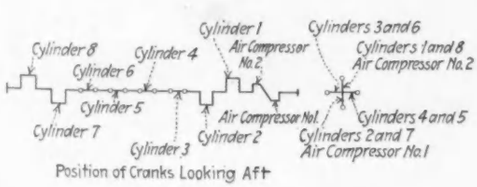


FIG. 7

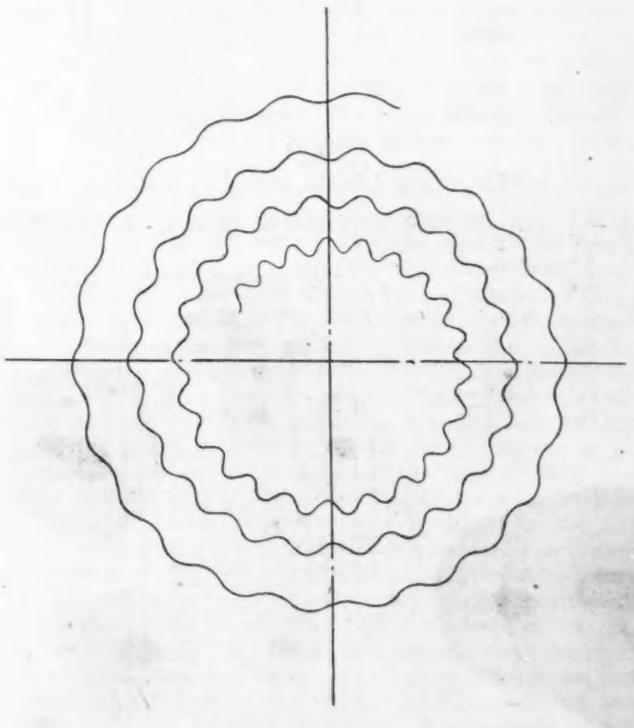


FIG. 9

of points, reducing to revolutions per minute and plotting. The revolutions per minute, it will be noted, vary from 298 to 430 four times in each revolution, while the engine is turning over at 350 r.p.m. Carrying the analysis

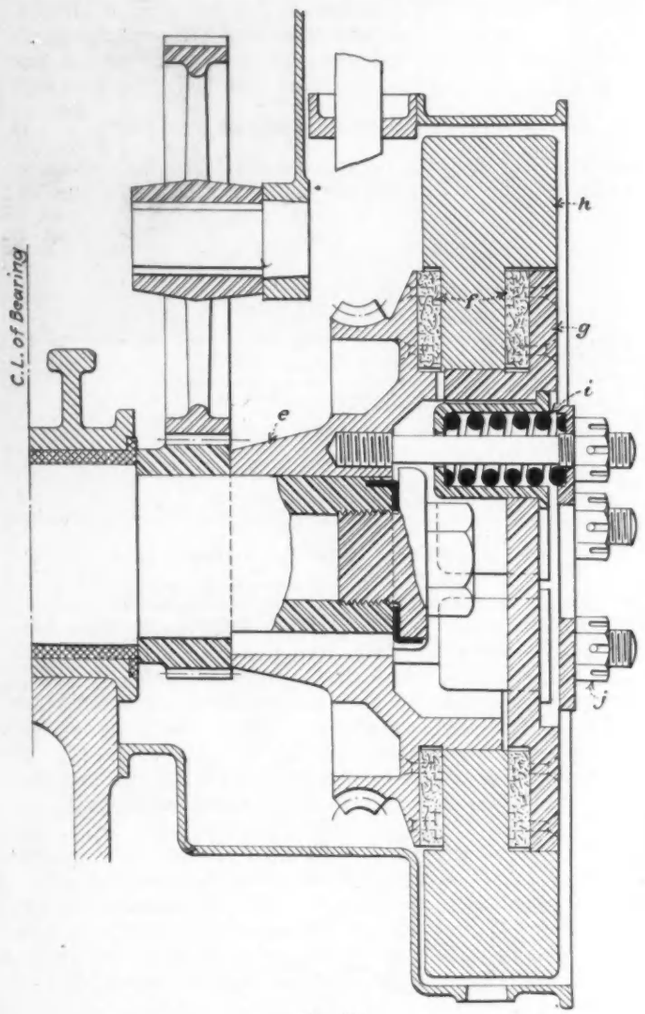


FIG. 10

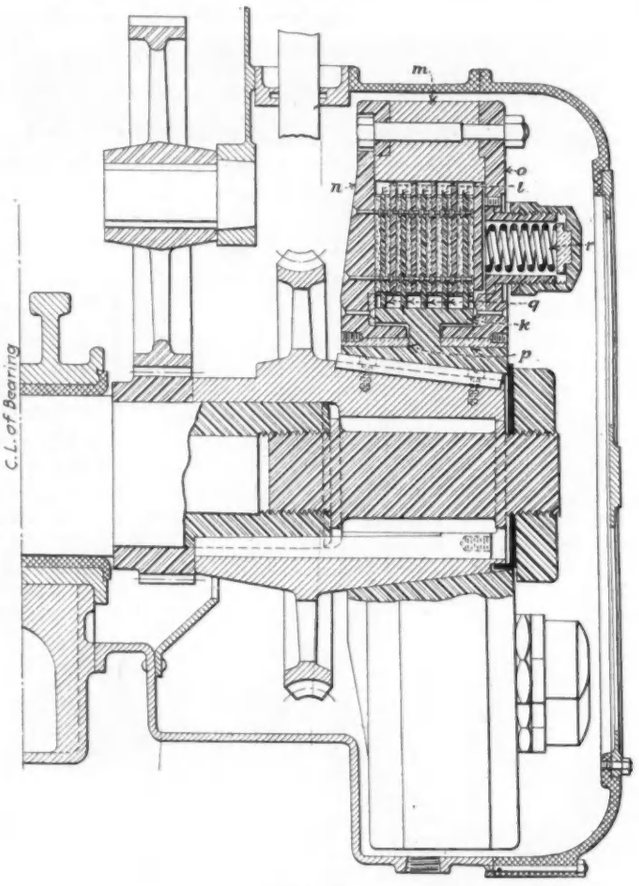


FIG. 12

a step further, curve d is the second derivative of curve b, $\frac{\delta_2 \theta}{\delta t^2}$, and the first derivative of curve c. It therefore represents the acceleration in revolutions per minute per second. This acceleration varies roughly from minus 10,000 r.p.m. per sec. to plus 10,000 r.p.m. per sec.

Fig. 9 shows the vibration record at 300 r.p.m. and 200 b.hp.; at which speed the engine ran very smoothly. The angular distance between successive waves is uniform. The analysis at this speed was not made; the

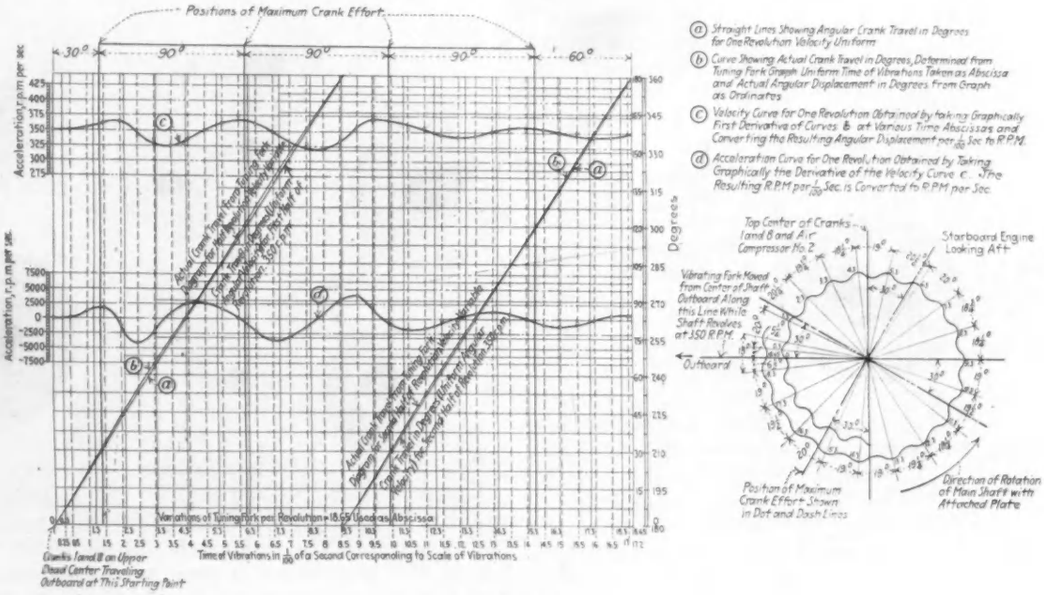

Positions of Maximum Crank Effort
30°
90°
90°
90°
60°
Acceleration, r.p.m. per sec.
Degrees
Variations of Tuning Fork per Revolution = 18.59 Degrees Abscissa
Time of Vibrations in 1/60 of a Second Corresponding to Scale of Vibrations
Cranks 1 and 8 on Upper Dead Center Traveling Outboard at This Starting Point
a Straight Lines Showing Angular Crank Travel in Degrees for One Revolution Velocity Uniform
b Curve Showing Actual Crank Travel in Degrees, Determined from Tuning Fork Graph Uniform Time of Vibrations Taken as Abscissa and Actual Angular Displacement in Degrees From Graph as Ordinates
c Velocity Curve for One Revolution Obtained by Taking Graphically First Derivative of Curves B at Various Time Abscissas and Converting the Resulting Angular Displacement per 1/60 Sec to R.P.M.
d Accelaration Curve for One Revolution Obtained by Taking Graphically the Derivative of the Velocity Curve C. The Resulting R.P.M. per 1/60 Sec. is Converted to R.P.M. per Sec.
Top Center of Cranks 1 and 8 and Air Compressor No. 2
Starboard Engine Looking Aft
Vibrating Fork Moved from Center of Shaft Outboard Along this Line While Shaft Revolves at 350 R.P.M.
Outboard
Position of Maximum Crank Effort Shown in Dot and Dash Lines
Direction of Rotation of Main Shaft with Attached Plate

FIG. 11

variation in crankshaft velocity was so slight that the curves could not be constructed satisfactorily. To remedy the difficulties encountered, the use of a Lanchester-type vibration damper was proposed and one was constructed.

Vibration Dampers

Fig. 10 shows the type of damper first tried. Keyed to the forward end of the crankshaft is the turning gear *e* which has riveted to it the asbestos friction blocks *f*. Turning gear *e* drives steel plate *g* by three accurately fitted jaws. Loosely fitted on the turning gear is the flywheel *h*, 36 in. in outside diameter and weighing 1000 lb. This flywheel is driven through the friction blocks riveted to the turning gear *e* and the steel plate *g*. Pressure to drive the flywheel is furnished by the five springs at *i*. The pressure can be adjusted by the nuts at *j*. The effect of this damper is to resist the tendency of the crankshaft to vibrate torsionally when the engine operates at a critical speed. The flywheel *h* tends to move uniformly, and any tendency of the crankshaft to vibrate is resisted by the friction surfaces at *f*. The vibration damper shown in Fig. 10 proved fairly satisfactory, reducing vibration to a marked degree. While vibration was still noticeable, it was possible to complete all tests without difficulty.

Fig. 10 shows friction blocks *f* solidly riveted to the driving members *e* and *g*. Better results were obtained by the use of two steel rings of ¼-in. boiler plate with asbestos brake-band lining riveted on both sides. These rings were placed between the flywheel *h* and pieces *e* and *g*, floating between them. This construction has the advantage of enabling quick replacement of the friction material. It is only necessary to remove the worn plates and insert spare plates with friction fabric attached ready for use. While the damper shown in Fig. 10 was fairly satisfactory, it had two rather serious defects. In the first place, wear on the friction material was somewhat rapid. The wear noted during a 24-hr. run made it evident that not more than from 250 to 300-hr. service could be expected from the friction material. The pressure on the friction material amounted to about 30 lb. per sq. in. of surface and was no doubt the cause of rapid wear. The second defect was the close adjustment required. While not delicate, the limits of satisfactory adjustment were too narrow for satisfactory use in service.

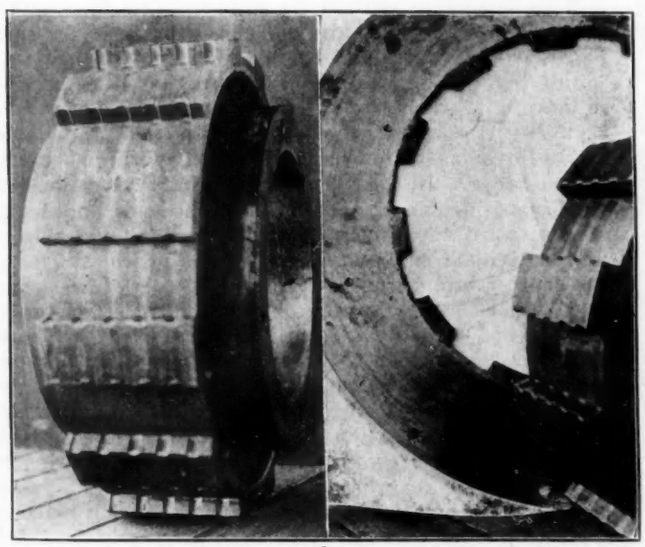


Fig. 13

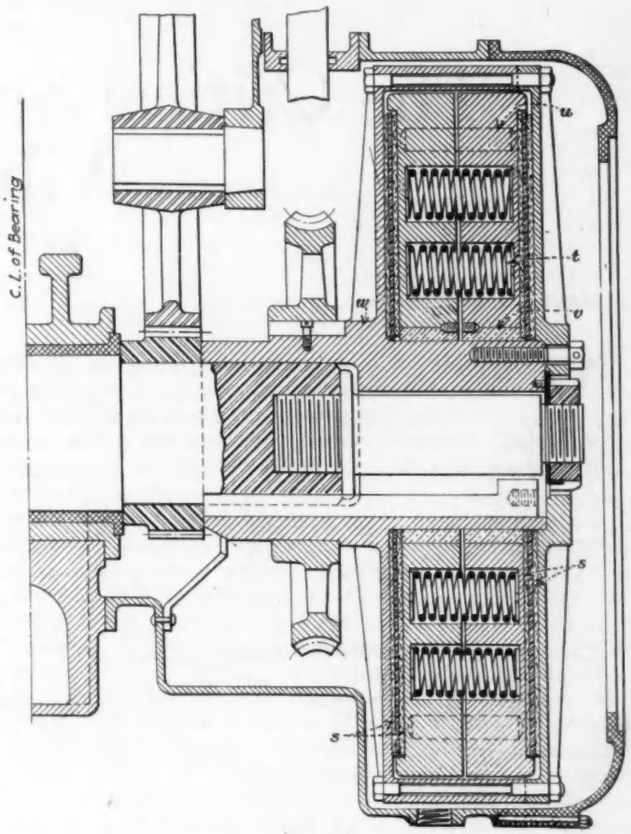


Fig. 14

Fig. 11 shows the effect on the engine as illustrated by the tuning-fork diagram and is an analysis of torsional vibration with a vibration damper installed. The variation in the velocity of the crankshaft is reduced very greatly from that shown in Fig. 8; it varies approximately from 325 to 360 r.p.m. At the time the data analyzed in Fig. 11 were taken, the damper was not working at its best, due to improper spring-tension.

To provide better service, the damper shown in Fig. 12 was designed and constructed. It is a multiple-disc-type vibration damper and consists of a hub *k*, solidly keyed to the crankshaft, driving five friction discs *l* by means of teeth cut upon its periphery. The flywheel part is made up of the pieces *m*, *n* and *o*, and rotates upon the graphite-spotted oilless bushings shown at *p*. Teeth are cut upon the bore of *m*, these driving the four friction discs shown at *q*. Pressure on the friction surfaces to drive the flywheel is furnished by the ten springs *r*. The friction material used is asbestos brake-band lining. This damper proved fairly satisfactory during the shop tests. Vibration was almost completely eliminated. The wear on the friction surfaces was reduced to a negligible amount, and the necessity for close adjustment was avoided. After about 222-hr. service aboard ship, however, the damper became very hot and pounded badly. Upon disassembly the condition shown in Fig. 13, was disclosed. It will be seen that deep grooves have been pounded by the friction discs into the teeth on the damper hub. The increase of clearance

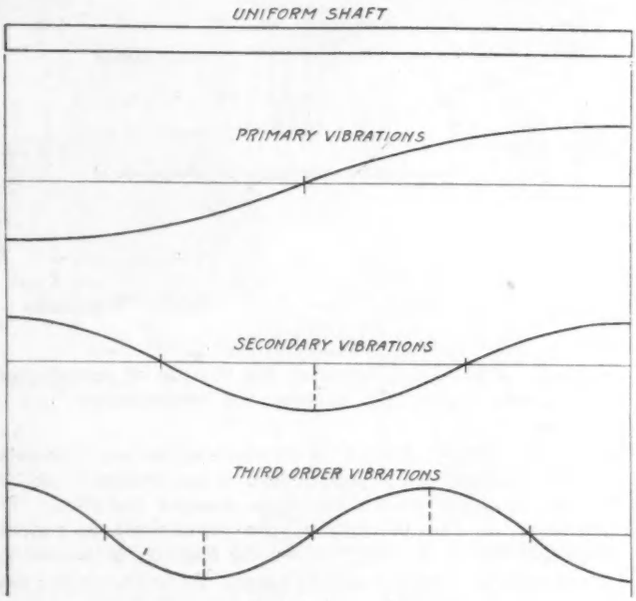
(*Concluded on page* 435)

The Critical Speeds of Torsional Vibration

By F. M. Lewis[1]

Metropolitan Section Paper *Illustrated with* Diagrams

VIBRATIONS of several kinds can occur in crankshafts, but the principal ones are transverse and torsional. The present article deals entirely with crankshaft torsional vibrations. Consider a simple case of torsional vibration. Imagine a weight to be suspended



Figs. 1, 2 and 3

vertically by a wire that is rigidly held at its upper end. If the weight is twisted around and then released, the weight and wire will slowly twist and untwist. Every combination of wire and weight will have a fixed period of vibration. This period will depend upon the size, length and elasticity of the wire, and the polar moment of inertia of the suspended weight. We know in a general way that if we increase the diameter of the wire, shorten its length or decrease the suspended weight, the frequency of vibration will be increased. Likewise, if we lengthen the wire, decrease its diameter or increase the weight, we will decrease the frequency of vibration.

If we increase the diameter of the wire to such an extent that we have a rod, the character of the motion is not changed but the vibrations occur with much greater rapidity. If we support the rod horizontally in bearings, we have the equivalent of an engine shaft. Instead of having the rod rigidly clamped at one point, let it be extended through this point and a weight fastened to the other end. If the ends are now twisted in opposite directions and then released, vibrations will occur as before. In the same manner as in the first case, the point on the shaft that was rigidly fastened did not move; in the second case there will be some point that will not move. This is the node. All of the shaft to one side of this node moves in the opposite direction to that on the other side. The motion is the same as if the shaft were rigidly clamped at the node. It is not necessary to have the weights fastened at the ends; they can be distributed along the shaft in any manner desired. Neither is it necessary to have the shaft of a uniform diameter throughout its length. Its diameter or its elasticity may change in any manner.

The period of the shaft depends upon three factors. These are the inertia of the rotating masses, its elasticity and length. Every combination of these will have a definite period of vibration. Let us take a uniform straight shaft along which the weight is distributed uniformly, or even one without attached weights, and subject this shaft to torsional vibration. If the shaft is not weighted, these vibrations will of course be extremely rapid. If then we plot the torsional deflection along the shaft, taking the instant when the deflection reaches its maximum, the result will be a sine curve such as is shown in Fig. 1. The node is at the center of the shaft. At the ends there is no turning moment but the vibration is at a maximum. At the node there is no motion, but the turning moment is at a maximum. Let us cut such a shaft into two equal parts. Each half could then vibrate in the same fashion as the whole vibrated before, in a sine curve such as is shown in Fig. 2. The halves will each vibrate with a frequency twice that of the original shaft. If the adjacent ends vibrate in the same phase, the motion would be just the same if they were joined together again. We thus see that it is possible to have vibrations in the shaft with two nodes, and that their frequency will be double those of the single-node vibrations. These will be called vibrations of the second order. Just as with the primary vibrations, at the loops which in this case are at the ends and center of the shaft, there is no turning moment and the vibration is at a maximum and, at the nodes which are one-quarter and three-quarters the length of the shaft from the ends, the turning moment is at a maximum and there is no motion. In like manner we might have divided the shaft into three equal parts. We would then have had vibrations of the third order, such as are shown in Fig. 3. There are three nodes and four loops in this form of vibration. In like manner we may have vibrations in an irregular shaft that are not only of primary order but may be of any higher order. In an irregular shaft, however, there is no fixed relation between the periods and node positions of the vibrations of different order. Each case gives different results.

We have so far considered only the vibrations of a sta-

[1]M. S. A. E.—Assistant professor of mathematics, Webb Academy, New York City.

tionary shaft. Let us impress on the entire shaft a uniform angular motion. It is evident that the character of the motion will not be altered as to either period or nodes. The nodes will now be points of uniform angular motion. Likewise, we might conceive the shaft to be under a uniform twisting moment; and this would not affect the motion. The stress and velocity in different parts of the shaft would fluctuate above and below, the constant mean stress and velocity fluctuating in exactly the same fashion as they fluctuated above and below the constant zero value in the unstressed stationary shaft. If the twisting moment in an engine shaft were always constant, we would not expect to have torsional vibrations. But in all prime-movers except electric motors and turbines, the torsion is not constant; it goes through a certain series of changes during each revolution of the engine. These irregularities in the turning moment of the engine induce torsional vibrations in the shaft. Moreover, shafting vibrations may be caused not only by irregularities in the power supplied to the shaft, but by irregularities in the power taken from the shaft.

Consider again the case of the weight hanging on the wire. If we start this swinging through a small angle and if at the end of every swing the weight is tapped, the swings will tend to increase in magnitude and will continue to increase until the work lost in friction during each swing is equal to the work imparted at the end of the swing by the impulse given. This is the case of synchronism between the impulses and the period of the wire and weight. If the period of the impulses is not equal to the period of the wire and weight, synchronism does not occur and the vibrations will not build up to a great value; for, while some of the impulses would come at the right instant to increase the magnitude of the swing, some, likewise, would come at the right instant to decrease it. The frequency of the turning-moment irregularities is always some multiple of the revolutions. In an eight-cylinder four-cycle Diesel engine with the cranks at 90 deg., such as the submarine engines under consideration, there would be four impulses per revolution. If the turning-moment diagram is irregular in character, so that the number of impulses per revolution cannot be readily seen, it can be analyzed by means of Fourier's theorem; that is, the harmonic elements can be picked out and the principal ones ascertained.[2]

Critical Speeds

For every period of vibration there is thus a corresponding critical speed. When the engine is running at this critical speed, the frequency of the impulses is equal to the frequency of the natural torsional vibrations. When we say "frequency of natural torsional vibrations," we mean vibrations of a free shaft. Attention is called to this because there are other ways in which the shaft might vibrate. It might, for instance, be held rigidly at one end; but when vibrating in such fashion the frequency is entirely different from that of the free shaft. In ordinary engine shafts only the lower critical speeds are of importance. In the submarine engines in question, the primary vibrations cause trouble in the charging condition and the secondary in the surface condition. No case has come to my attention in which a critical speed higher than that of second order was within the operating speed of the engine. In the design of engines we ought to avoid these critical speeds,

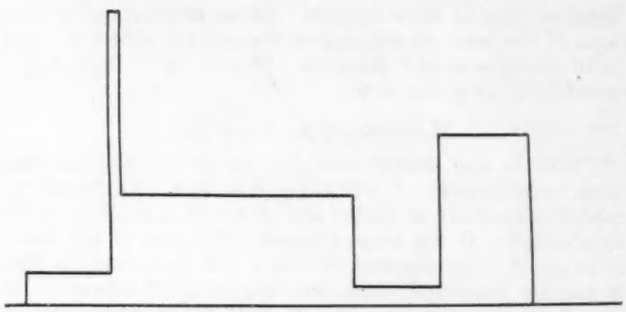


Fig. 4

for we should expect serious trouble whenever the engine approximates them.

Attention is called to the fact that the period is not determined wholly by the engine itself, but by the entire line of shafting in any way connected with the engine. An engine that would give entire satisfaction in one place might develop serious trouble when used in a different shafting line-up, or an engine might run smoothly with a shaft that had vibrated badly with another. It is not a fault of the engine, but of the entire shaft. If, when the engine and shaft are in the design stage, it is possible to calculate the natural frequency of vibration of the shaft, it can be determined whether trouble from torsional vibration is to be expected in that particular shaft. If trouble is indicated, it will then be possible to tell what alterations would avoid trouble from torsional vibration. Small vibrations cannot be avoided. They will always be present no matter how the shaft is arranged. It is not necessary to avoid them, for they are not necessarily dangerous. It is only when synchronism occurs, and the ordinary small vibrations are allowed to build up and increase in magnitude, that dangerous vibration occurs. This can be avoided by proper design, having the subject of vibration in mind. If possible, the shaft should be so designed that its highest operating speed is lower by a safe margin than its primary critical speed. If that is not possible, its operating speed should occur between two of its critical speeds. The critical speed can often be greatly altered by judicious relatively slight changes in the shaft. Still, there might exist cases where no practical change in the shafting would eliminate the critical speeds. In such cases dampers offer the only solution.

Before taking up the mathematics of the method, I will indicate how the frequency of vibration is affected by changes in the shaft. These changes follow relatively simple laws. The addition of mass inertia on a node has no effect; that is, no weight that we can add here will materially affect the frequency of vibration. Stiffness here is all-important. Changes in the size of a shaft in this vicinity are very effective, the critical speed being raised for increases in the size of the shaft and lowered for decreases. On a loop, the inverse is true. Here, weight is all-important and stiffness has little or no effect. An increase of weight will lower the critical speed and a decrease will raise it. If we change the shafting size in a fixed proportion throughout the shaft, the critical speed will vary approximately as the square of the diameter. If we change the mass inertia in the same proportion throughout the shaft, the critical speed will vary inversely as the square root of the polar moment of inertia. These uniform changes will not affect the position of the nodes. If we have two shafts that are geometrically similar, their critical speeds will be in the

[2]See Synchronous Torsional Vibrations of Shafting, by Hermann Frahm, *Journal of the American Society of Naval Engineers*, vol. XIV.

inverse ratio of their lengths. These relations give some idea of the way we can expect the critical speeds to vary with changes in the shafting. The proof of these statements will be given later.

Mathematical Analysis

There is one simple case for which the solution has long been known. I will state this first. Let there be a length of shaft to either end of which a rotating mass is attached. If the mass moment of inertia of the shaft is so small in proportion to that of the end weights that it can be neglected, then the frequency of vibration in complete vibrations per second is given by the equation $n = \frac{1}{2}\pi\sqrt{[g\,G\,J_s\,(J_1 + J_2) \div l\,J_1\,J_2]}$ where J_1 and J_2 are the polar moments of inertia of the end masses about the shaft center in length, and the weight unit J_s is the polar moment of inertia of the shaft if it is uniform, or the equivalent moment of inertia if it is not uniform. This is in length units only. G is the coefficient of elasticity in shear and l is the length of the shaft. It will be noted that, under the given assumptions, primary vibrations only are possible. Many cases will fall under this simple formula.

As previously stated, the period of the shaft depends upon the inertia of the rotating masses, its stiffness and length. The inertia of the rotating masses is measured by the mass polar moment of inertia. The amount of this mass polar moment of inertia per unit of length will be denoted by J_w. The stiffness of the shaft is measured by the product GJ_s, where J_s is the moment of inertia of that portion of the shaft that takes torsion and G the coefficient of elasticity for shearing. For a section of simple shaft to which nothing is attached, it follows that $J_w = wJ_s$, where w is the unit weight of the shaft material. If there is fastened on the shaft an armature or other mass, so that J_w does not equal wJ_s, that shaft is said to be a loaded shaft.

The use of the product GJ_s as a measure of stiffness follows directly from the equation for the deflection of shafts.

where
$$\Theta = \frac{Ml}{GJ_s} \qquad (1)$$

M = the twisting moment
l = length of the shaft
Θ = torsional deflection in radians

That is, torsional deflection under a given twisting moment and length is inversely proportional to GJ_s. It may happen, regarding the cranks of an engine, that GJ_s has no direct meaning. If we can determine the torsional deflection of such a shaft under any given twisting moment, we can determine by equation (1) an equivalent GJ_s.

I will define a step variable as being a function which remains constant for a certain range of the independent variable and then jumps to a new constant value for the next consecutive range, and so on for its entire length. The graph of some such function might be as in Fig. 4. By choosing suitable breaking points, every shaft can be considered as being a step variable. Over each section or step, both J_w and GJ_s are considered as being constant. Unless both the shaft and its load are of uniform dimensions throughout, the step they will have will, of course, not be constant. In this case, equivalent constant values can be calculated. The equivalent J_w is equal to the total mass moment of inertia for the step, divided by the length of the step. The equivalent GJ_s for the step is determined by finding the total torsional deflection under a given twisting moment. Then, from equation (1), $GJ_s = \frac{Ml}{\Theta}$ will be the equivalent value. The steppage used for the shaft in Fig. 5 should be noted. The calculator must use judgment in choosing the breaking points, so that the equivalent shaft thus obtained will closely approximate the actual one. In general, the use of steps of too short a length will involve much more labor, without any compensating gain in accuracy.

The mathematical demonstration of the method is as follows:

M = the twisting moment in the shaft
GJ_s = the value previously explained
Θ = the twist of the shaft in radians
x = the length variable for the shaft
g = the gravity constant
J_w = the mass polar moment of inertia per unit of length
l = the length of any step

Consider any step and take a section of length δx. Let the increment of twist in the length δx be $\delta\Theta$. Then rewriting equation (1), we get

$$M = GJ_s \cdot \frac{\delta\Theta}{\delta x} \qquad (2)$$

Differentiating this we get

$$\delta M = GJ_s \frac{\delta^2\Theta}{\delta x^2}\,\delta x \qquad (3)$$

Let the acceleration of this small section be $\frac{\delta^2\Theta}{\delta t^2}$

Then the increment of twisting moment in the length δx due to the inertia forces will be

$$\delta M = \frac{J_w}{g} \cdot \frac{\delta^2\Theta}{\delta t^2}\,\delta x \qquad (4)$$

Equating (3) and (4) we get

$$GJ_s \cdot \frac{\delta^2\Theta}{\delta x^2} = \frac{J_w}{g} \cdot \frac{\delta^2\Theta}{\delta t^2} \qquad (5)$$

or

$$\frac{\delta^2\Theta}{\delta x^2} = \frac{J_w}{gGJ_s} \cdot \frac{\delta^2\Theta}{\delta t^2} \qquad (6)$$

Equation (6) is in the form of the general equation for all harmonic motion. We are only interested, however, in the simple harmonic motions that can take place. For simple harmonic motion, the general equation is

$$\frac{\delta^2\Theta}{\delta t^2} = -k^2\Theta \qquad (7)$$

If t_1 is the time of a double oscillation, then the familiar solution of equation (7) is given by

$$t_1 = \frac{2\pi}{k}$$

Or, if n is the number of complete vibrations per second

$$n = \frac{k}{2\pi} \qquad (8)$$

Squaring,

$$k^2 = 4\pi^2 n^2$$

So that

$$\frac{\delta^2\Theta}{\delta t^2} = -4\pi^2 n^2\Theta \qquad (9)$$

Substituting (9) in (6) we get

$$\frac{\delta^2\Theta}{\delta x^2} = -\frac{4\pi^2 J_w}{gGJ_s} n^2\Theta \qquad (10)$$

The general solution of (10) is given by the equation

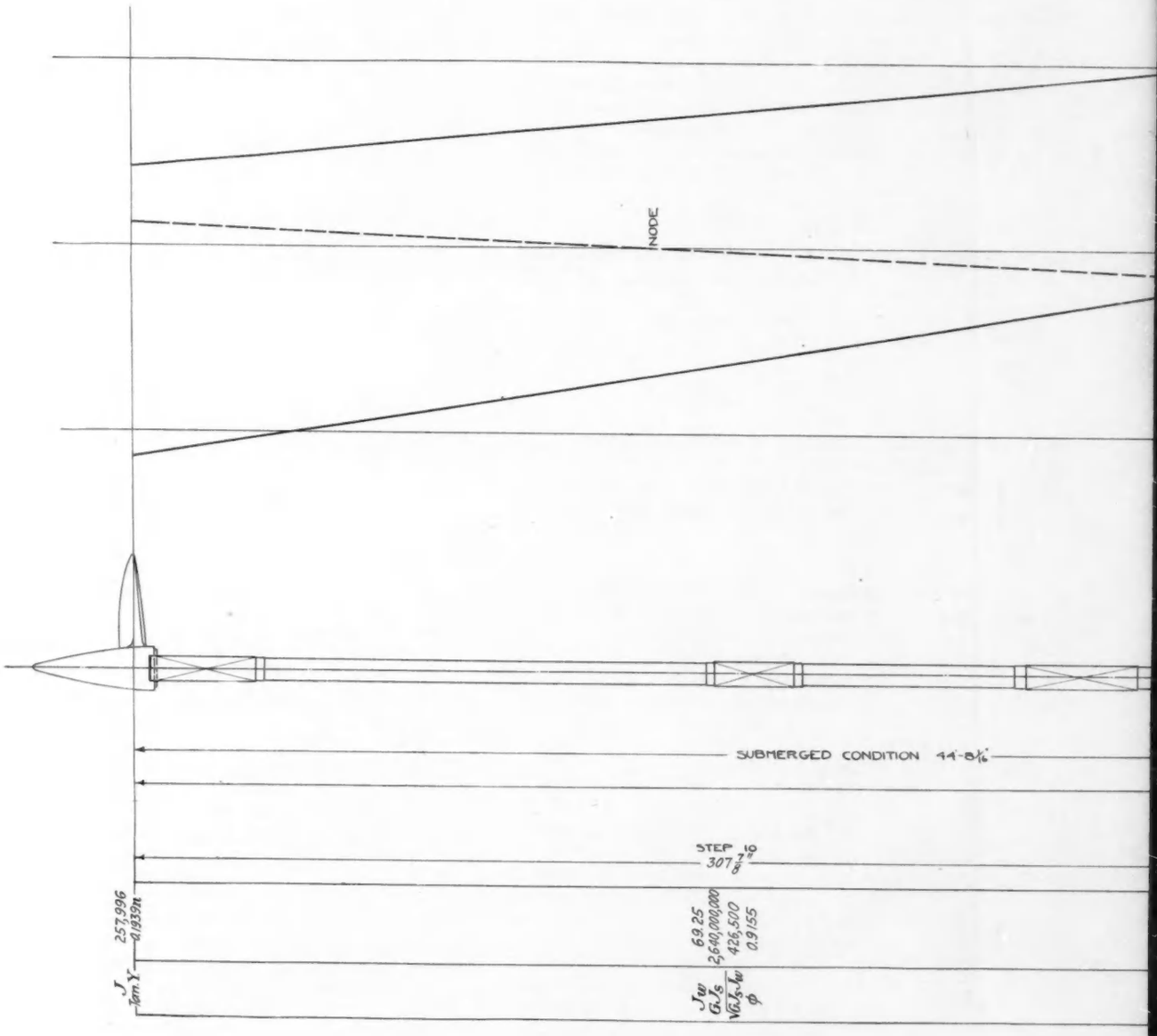
$$\Theta = \alpha\cos(\beta x + \gamma) \qquad (11)$$

From which, by differentiation,

$$\frac{\delta\Theta}{\delta x} = -\alpha\beta\sin(\beta x + \gamma) \qquad (12)$$

$$\frac{\delta^2\Theta}{\delta x^2} = -\alpha\beta^2\cos(\beta x + \gamma) \qquad (13)$$

The symbols α, β and γ are constants. They must


NODE
SUBMERGED CONDITION 44'-8 1/16"
STEP
307 7/8"
10
257,996
0.1339n
69.25
2,640,000,000
426,500
0.9155
J
Jm Y
Jw
G.Js
Vo.Js.lw
ϕ

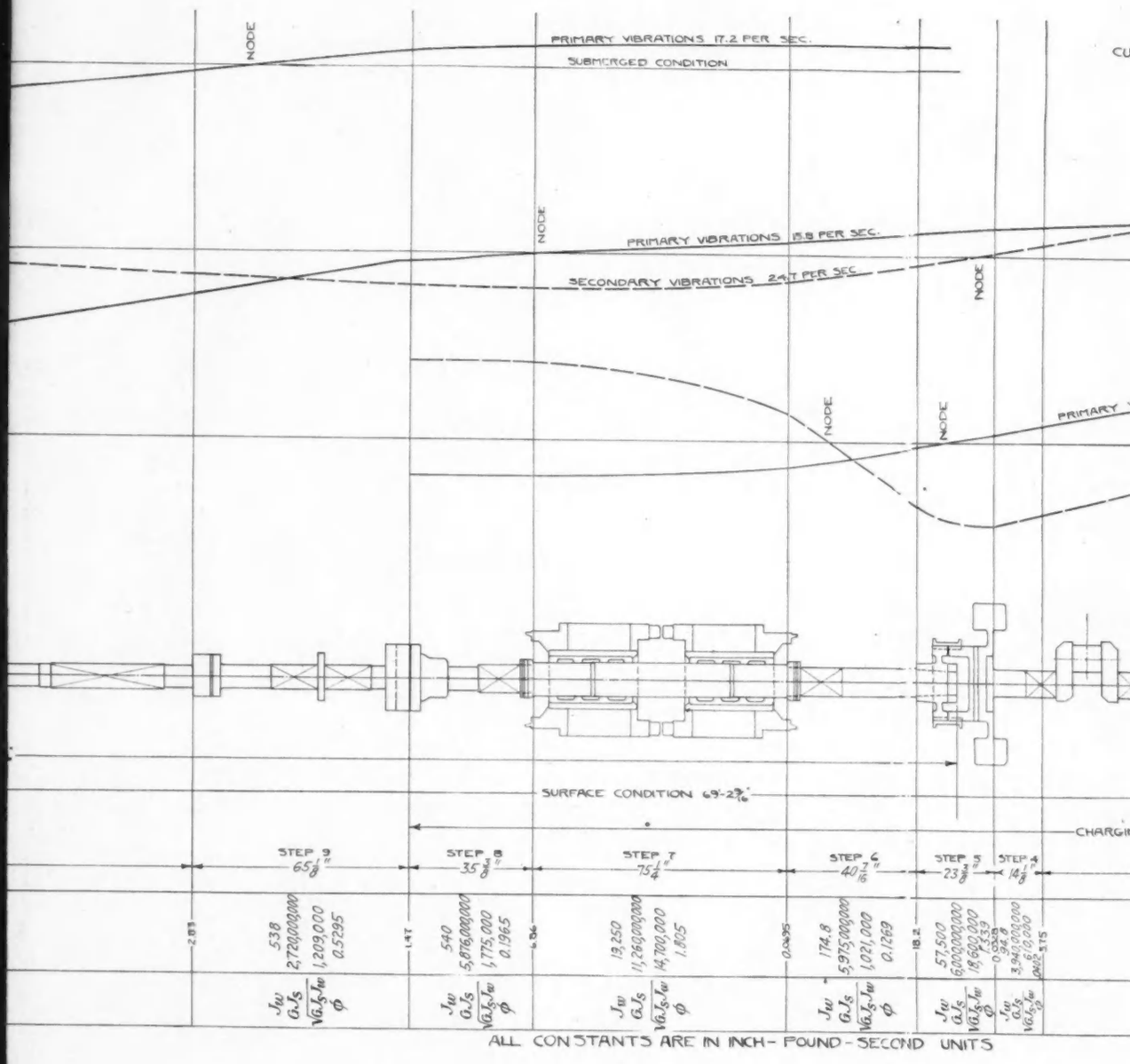
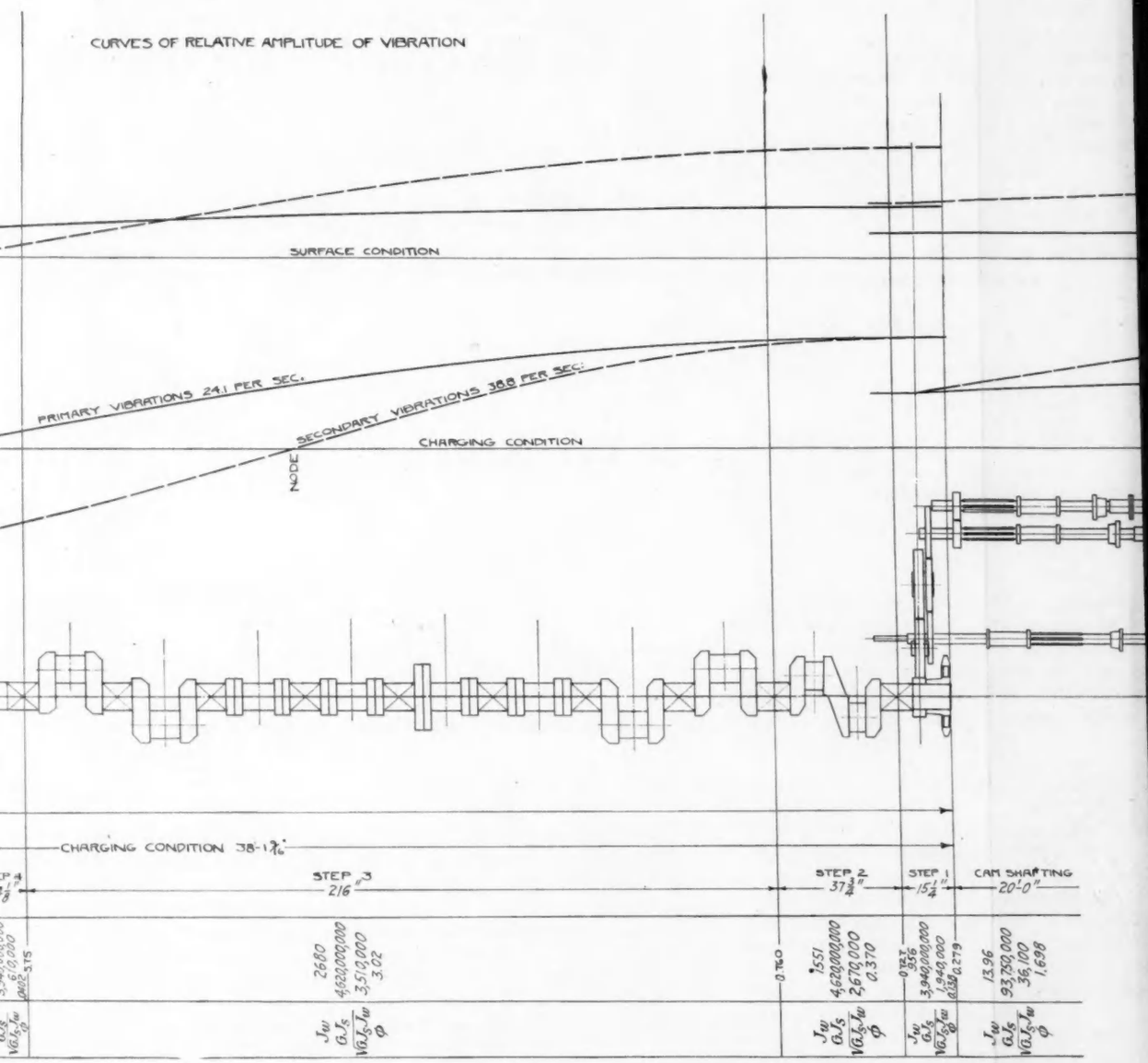
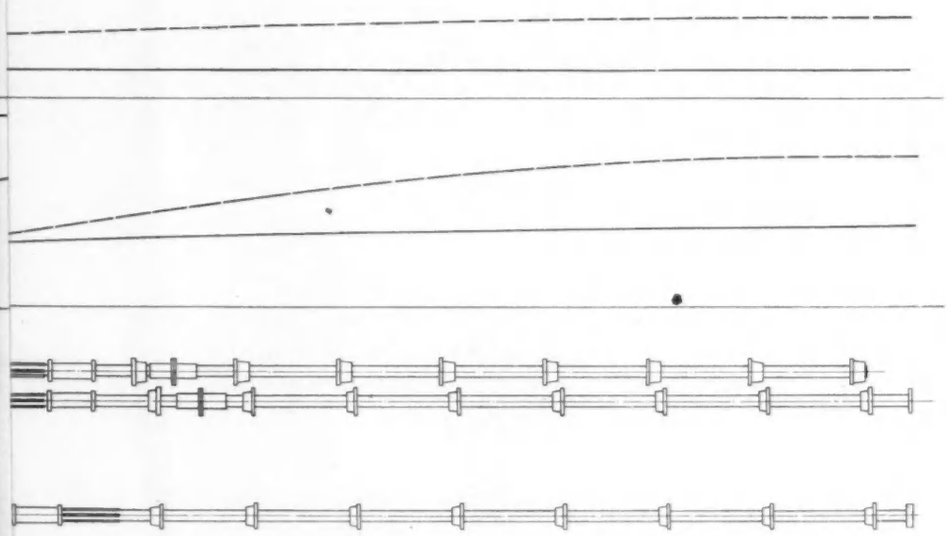

NODE
PRIMARY VIBRATIONS 17.2 PER SEC.
SUBMERGED CONDITION
NODE
PRIMARY VIBRATIONS 15.8 PER SEC.
SECONDARY VIBRATIONS 24.7 PER SEC.
NODE
NODE
NODE
PRIMARY
SURFACE CONDITION 69-2⅞°
CHARGI
STEP 9
65⅛"
STEP 8
35 Dia"
STEP 7
75¼"
STEP 6
40 7/16"
STEP 5
23 Dia"
STEP 4
14⅜"
2.83
1.47
4.84
0.435
18.2
538
2,720,000,000
1,209,000
0.5295
540
5,876,000,000
1,775,000
0.1965
19,250
11,260,000,000
14,700,000
1.805
174.8
5,975,000,000
1,021,000
0.1269
57,500
6,000,000,000
18,600,000
0.0038
94.8
3,940,000,000
610,000
0.0012
5.75
Jw / GJs / √6Js Jw / φ
ALL CONSTANTS ARE IN INCH-POUND-SECOND UNITS

FIG. 5


CURVES OF RELATIVE AMPLITUDE OF VIBRATION
SURFACE CONDITION
PRIMARY VIBRATIONS 24.1 PER SEC.
SECONDARY VIBRATIONS 38.8 PER SEC.
CHARGING CONDITION
NODE
CHARGING CONDITION 38-1 7/16"
STEP 3
2 1/16"
STEP 2
37 3/4"
STEP 1
15 1/4"
CAM SHAFTING
20'-0"
0.760
2680
4,620,000,000
3,510,000
3.02
1551
4,620,000,000
2,670,000
0.370
0.127
956
3,940,000,000
1,940,000
0.279
13.96
93,750,000
36,100
1.698



SUMMARY

	CHARGING		SURFACE		SUBMERGED
	PRIMARIES	SECONDARIES	PRIMARIES	SECONDARIES	PRIMARIES
CALCULATED PERIOD, VIBRATIONS PER SEC.	24.1	38.8	15.8	24.7	17.2
CORRESPONDING CRITICAL SPEED, R.P.M.	361	584	237	370	
OBSERVED SPEED OF MAXIMUM VIBRATION	350			365	

M SHAFTING
-20'-0"

93,750,000
36,100
1.698

$\frac{W}{GJ_P}$
$\sqrt{\frac{GJ_P}{WJ_m}}$
ϕ

U.S. SUBMARINES S4-S13
TORSIONAL VIBRATION ANALYSIS OF SHAFTING

be determined for each step so as to satisfy, first, the differential equation for that step, and, second, the end conditions for that step. It will be noted that n, the vibrations per second, which is the answer we are seeking, enters into equation (10). It will therefore enter into the constants β and γ in every step. The value of n which enables us to satisfy every differential equation and every end condition throughout the entire length of shafting will be the solution of the problem. To simplify the explanation we will assume for the present that this value of n is known. Substituting (11) and (13) in (10) and simplifying, we get

$$\beta^2 = \frac{4\pi^2 J_w}{gGJ_s} n^2 \qquad (14)$$

Or,

$$\beta = \frac{2\pi n \sqrt{J_w}}{\sqrt{gGJ_s}} \qquad (15)$$

We will investigate first the end conditions at the beginning of the shaft. Let there be fastened to this end of the shaft a rotating mass of polar moment of inertia J_1. Then, if M is the twisting moment at this end

$$M = \frac{J_1}{g} \cdot \frac{\delta^2 \Theta}{\delta t^2} \qquad (16)$$

Also,

$$M = GJ_s \frac{\delta \Theta}{\delta x} \qquad (2)$$

Equating

$$\frac{J_1}{g} \cdot \frac{\delta^2 \Theta}{\delta t^2} = GJ_s \cdot \frac{\delta \Theta}{\delta x} \qquad (17)$$

From (9),

$$\frac{\delta^2 \Theta}{\delta t^2} = -4\pi^2 n^2 \Theta$$

From (11),

$$\Theta = \alpha \cos (\beta x + \gamma)$$

From (12),

$$\frac{\delta \Theta}{\delta x} = -\alpha\beta \sin (\beta x + \gamma)$$

Substituting these values in (17), we get

$$\cos (\beta x + \gamma) \frac{4\pi^2 n^2 J_1}{gGJ_s} = \beta \sin (\beta x + \gamma) \qquad (18)$$

Since we are considering the beginning of the shaft, $x = 0$ and (18) reduces to

$$\tan \gamma = \frac{2\pi n J_1}{\sqrt{gGJ_s J_w}} \qquad (19)$$

This is the condition to be satisfied at the beginning of the shaft. If nothing is attached to the shaft at this point, tan γ reduces to zero. We have now determined the constants β and γ for the first step in terms of n and the known properties of the shaft. The symbol α can have any value for this step. It is a measure of the amplitude of vibration at the beginning of the shaft. We will now investigate the end conditions for the second step. We will use the subscript 1 to denote the first step; 2 the second step, etc.

From (15)

$$\beta_2 = \frac{2\pi n \sqrt{J_{w_2}}}{\sqrt{gG_2 J_{s_2}}} \qquad (20)$$

At the end of the first step

$$M_1 = G_1 J_{s_1} \frac{\delta \Theta}{\delta x} \qquad (21)$$

Substituting the value for $\frac{\delta \Theta}{\delta x}$ and β_2 given by (12) and (20) in (21), we get

$$M_1 = -\frac{\alpha_1 2\pi n \sqrt{G_1 J_{s_1} J_{w_1}}}{\sqrt{g}} \sin (\beta_1 l_1 + \gamma_1) \qquad (22)$$

Likewise, at the beginning of the second step, taking l as the length of the first step and since for this point $x = 0$

$$M_2 = -\frac{\alpha_2 2\pi n \sqrt{G_2 J_{s_2} J_{w_2}}}{\sqrt{g}} \sin \gamma_2 \qquad (23)$$

The turning moments on each side of the break are equal. Therefore, equating M_1 and M_2 and clearing, we get

$$\alpha_1 \sqrt{G_1 J_{s_1} J_{w_1}} \sin (\beta_1 l_1 + \gamma_1) = \alpha_2 \sqrt{G_2 J_{s_2} J_{w_2}} \sin \gamma_2 \qquad (24)$$

Also at the break the deflections must be equal, or

$$\alpha_1 \cos (\beta_1 l_1 + \gamma_2) = \alpha_2 \cos \gamma_2 \qquad (25)$$

I will now show how these equations and conditions can be expressed graphically. Turning to Fig. 6, we lay off a distance *oa* of length equal to unity and a perpendicular *ac* equal to tan γ as given by equation (19). Then $\angle coa = \gamma$ and $oc = \alpha$. Substituting the value of β given by (15) in (11) we get

$$\Theta = \alpha_1 \cos \left\{ \frac{2\pi n \sqrt{J_{w_1}}}{\sqrt{gG_1 J_s}} x + \gamma_1 \right\} \qquad (26)$$

The angles are in radians. It will be convenient to put them in degrees. In degrees,

$$\Theta = \alpha_1 \cos \left\{ \frac{360 n \sqrt{J_{w_1}}}{\sqrt{gG_1 J_{s_1}}} x + \gamma_1 \right\} \qquad (27)$$

When $x = l_1$

$$\Theta = \alpha_1 \cos \left\{ \frac{360 n \sqrt{J_{w_1}}}{\sqrt{gG_1 J_{s_1}}} l_1 + \gamma_1 \right\} \qquad (28)$$

The following expression should be calculated for each step. We will call it the angular function, denote it by the symbol ϕ and consider l as the length of the particular step with which we are working.

$$\phi = \frac{360 \sqrt{J_w} l}{\sqrt{gGJ_s}} \qquad (29)$$

To satisfy equation (28) graphically, we then lay off from *oc* an angle equal in degrees to ϕ *n*, and draw the arc *dc*. We then erect a perpendicular *de*. Then, if *oa* represents the deflection at the beginning of the shaft, *oe* will represent the deflection at the end of the first step. Let *de* be denoted by y_1 and a distance $ef = Y_1$ be laid off so that

$$Y_1 = y_1 \frac{\sqrt{G_1 J_{s_1} J_{w_1}}}{\sqrt{G_2 J_{s_2} J_{w_2}}} \qquad (30)$$

It is now seen that $of = \alpha_2$ and that $\angle foa = \gamma_2$ for equation (25) is thus satisfied. Since $\alpha_1 \sin (\beta_1 l_1 + \gamma_1) = y_1$ and $\alpha_2 \sin \gamma_2 = Y_1$ we have satisfied equation (24).

Lay off now from *of* an angle $\phi_2 n$ and proceed as for the second step until the end of the shaft is reached, say on the line *oj* or *oj'*. At the end of the shaft suppose a rotating mass of moment of inertia J_e to be attached. Then, if M_e is the turning moment due to the acceleration of this rotating mass,

$$M_e = -\frac{J_e}{g} \cdot \frac{\delta^2 \Theta}{\delta t^2} \qquad (31)$$

And

$$M_e = G_e J_{se} \frac{\delta \Theta}{\delta x} \qquad (32)$$

Equating (31) and (32) and proceeding in the same manner as that by which we derived equation (18), we get

$$\tan (\beta_e l_e + \gamma_e) = -\frac{2\pi n J_e}{\sqrt{gG_e J_{se} J_{we}}} \qquad (33)$$

The *e* subscripts denote the end or last step. Equation (33) will be satisfied if

$$\beta_e l_e + \gamma_e = \angle aoj + m\pi$$

where m equals 0 or any integer, the $\angle aoj < \pi$ and

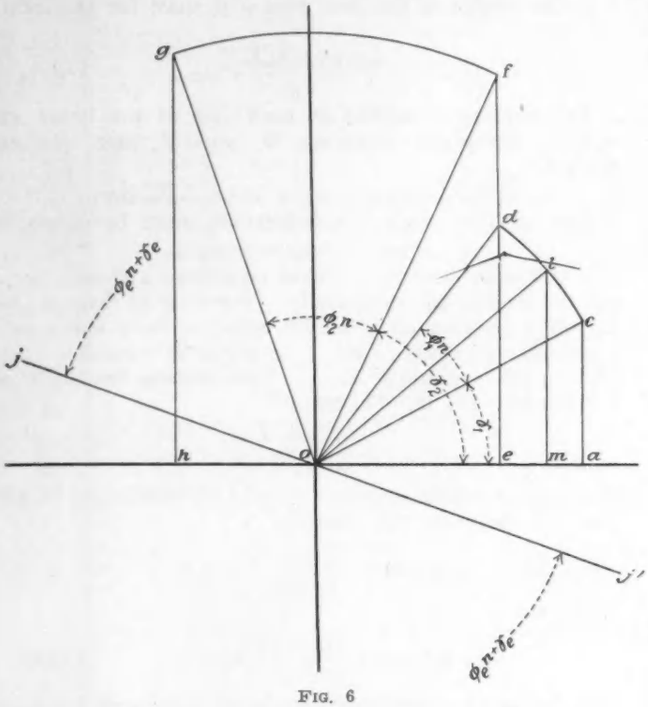


FIG. 6

$$\tan \angle aoj = -\frac{2\pi n J_2}{\sqrt{gG_e J_{se} J_{we}}}$$

If nothing is attached to this end of the shaft, $\beta_e l_e + \gamma_e$ will equal $\pi + m\pi$.

For each value of the integer m, some value of n will satisfy all the equations and end conditions throughout the shaft and will therefore be one of the natural frequencies of vibration of the shaft. When $m = 0$, n will be the frequency of the vibrations of primary order, for we see from the polar diagram that Θ will pass through the 0 value once; that is, there will be one node. When $m = 1$ we see that Θ will pass through the 0 value twice and we will have vibrations of secondary order. We wish to find then the values of n by which the construction in the polar diagram will cover a multiple of 180 deg. If we are solving for primary vibrations, we wish to cover 180 deg.; if for secondary, 360 deg.; if for vibrations of the third order, 540 deg.; etc. The value of n which will do this is determined by trial and error. I will now review the actual procedure of calculation for easy reference.

(1) The shaft is divided into steps of suitable length

(2) For each of these steps an equivalent J_w and GJ_s is calculated. In other words, we have substituted for the actual shaft an equivalent shaft made up of steps of uniform size and loading, and we note that masses attached to the extreme ends of the shaft are not considered as belonging to any step

(3) Calculate for each step the angular function given by equation (29) and the break function given by equation (30) then equals

$$\sqrt{GJ_s J_w}$$

(4) If to the ends of the shaft rotating masses are fastened, calculate for each end the tangent function given by equation (19) or (33)

$$\tan \gamma_1 \text{ or } -\tan\ (\beta_e l_e + \gamma_e) = \frac{2\pi n J_1}{\sqrt{gGJ_s J_w}}$$

(5) Take one end of the shaft as the beginning and the other as the end; calculate for each break the ratio of the break functions, marking them on the diagram of the shaft for convenience. That is find

$$\frac{Y_1}{y_1}, \quad \frac{Y_2}{y_2}, \quad \frac{Y_3}{y_3}, \text{ etc.}$$

(6) Assume some value for n and, starting at the beginning of the shaft, lay off in the diagram oa equal to unity and ac equal to $\tan \gamma_1$

From oc lay off an angle $doc = \phi_1 n$ and multiply de in the ratio $\frac{Y_1}{y_1}$. Lay off $\angle fog = \phi_2 n$ and proceed in this way until the end of the shaft is reached

Lay off finally the angle whose tangent has been calculated for the rotating mass at the end of the shaft

The total angle we have now passed over will be a measure of the closeness of the first assumption for n, from which a second approximation can be made, and thus on to the required degree of closeness. Or, we might plot a curve of total angle and n and find for what values of n this curve cuts the 180 or 360-deg. line, whichever is required. Once the functions have been calculated for each step, the approximate diagrams can be constructed very rapidly

It is evident at once that a diagram which fulfills the necessary conditions, that is, one which covers a multiple of 180 deg., is a diagram of relative angular shaft deflections due to torsional vibration such as Fig. 1. In Fig. 6, for instance, oa is the deflection at the beginning of the shaft, oe the deflection at the end of the first step, oh at the end of the second step, etc. The deflection at any point within the step is found by dividing the angle for the step, as cod, in the same ratio as the point divides the length of the step. To find the deflection at the middle of the first step, for instance, draw ol bisecting the angle doc. Then om is the deflection. In this manner the position of the nodes is instantly determined. A node, being a point of zero deflection, is the point on any step where its arc cuts the vertical through the origin.

It is seen that, if we change any property of a shaft in the same proportion throughout its length, the polar diagram will remain unchanged.

By equation (28) the angle corresponding to each step is equal to

$$\phi_n = \frac{360\sqrt{J_w} l n}{\sqrt{gGJ_s}}$$

So that we can write for such changes,

$$\frac{360\sqrt{J_w} l n}{\sqrt{gGJ_s}} = \text{a constant.}$$

From this it follows that for changes in J_w only, using $\propto$ to mean "varies as,"

$$n \propto \frac{1}{\sqrt{J_w}}$$

For changes in GJ_s only,

$$n \propto \sqrt{GJ_s}$$

For changes in l only,

$$n \propto \frac{1}{l}$$

For similar engines,

$$n \propto \frac{1}{l}$$

which are the relations previously stated.

There are a number of special cases which we have not so far taken up, such as gears and turbines in mesh with the main shaft, camshafts driven by it, flexible couplings and the like. To illustrate the general treatment of such cases I will give the treatment for a flexible coupling. It is assumed that a certain amount of flexibility is to be placed between two steps. Let F be the twisting moment in such a coupling and θ the corresponding deflection. Then we will write

$$k = \frac{\delta F}{\delta \theta}$$

Take the value of k at the point corresponding to mean torque. Let θ_1 be the abscissa in the polar diagram that we have obtained at the end of the previous step and let θ_2 be the abscissa when we have passed through the elastic clutch. Then, if M is the torsion in the clutch due to vibration,

$$M = k\,(\theta_2 - \theta_1)$$

$$= \frac{k\,(\theta_2 - \theta_1)}{\theta_1}\,\theta_1 \qquad (34)$$

Since by equation (11)

$$\theta_1 = \alpha_1 \cos\,(\beta_1 x + \gamma_1)$$

$$M = \alpha_1 k \left(\frac{\theta_2 - \theta_1}{\theta_1}\right) \cos\,(\beta l + \gamma) \qquad (35)$$

By equation (22),

$$M = -\,\alpha_1 \frac{2\pi n \sqrt{G_1 J_{s1} J_{w1}}}{\sqrt{g}}\,\sin\,(\beta_1 l_1 + \gamma_1)$$

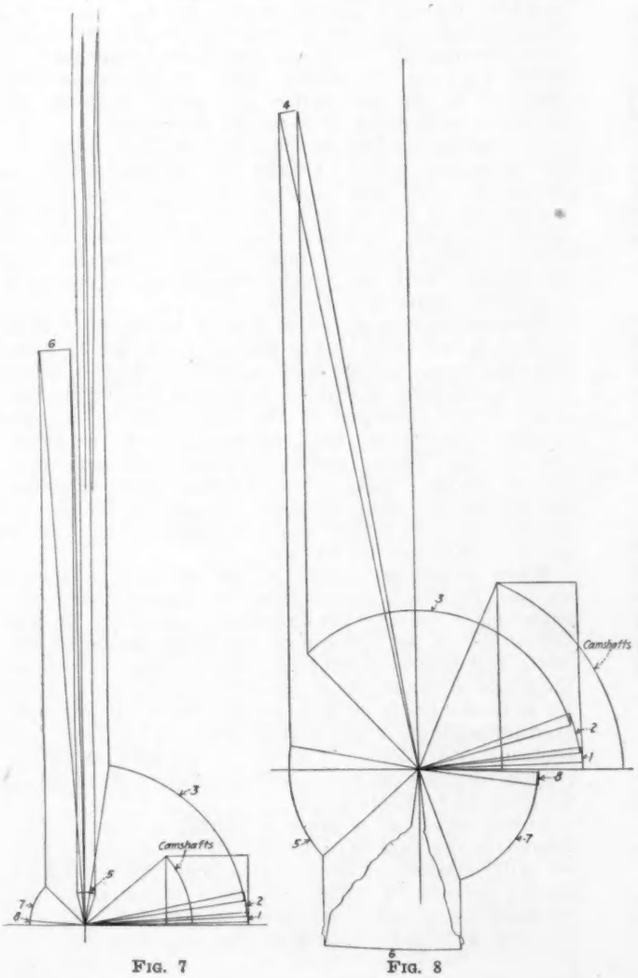
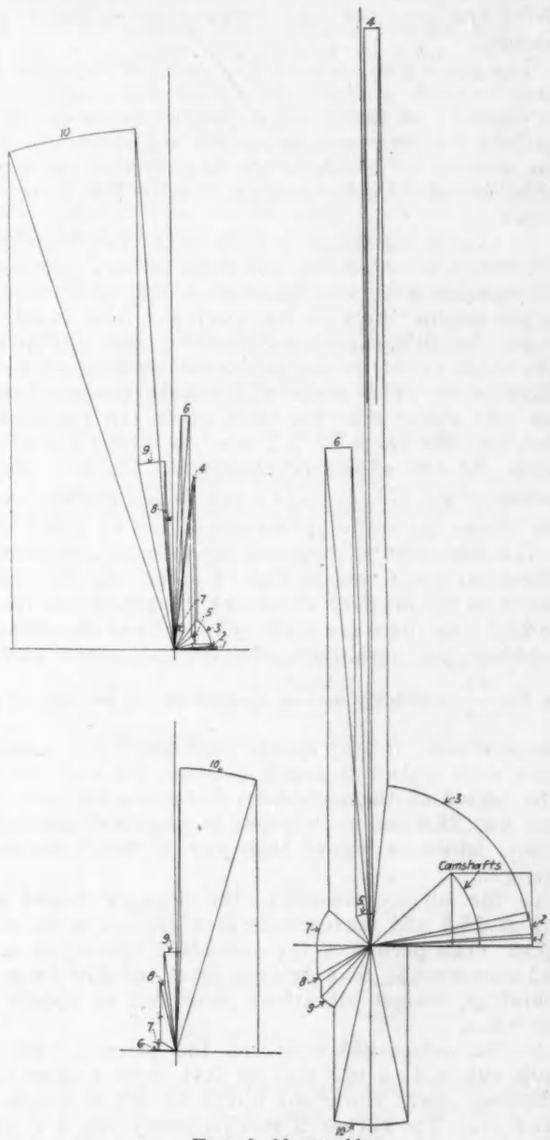


FIG. 7

FIG. 8



FIGS. 9, 10 AND 11

Equating (22) and (35) and remembering that

$$\frac{\theta_1}{\alpha_1} = \cos\,(\beta l + \gamma) \text{ and } y_1 = \alpha_1 \sin\,(\beta_1 l_1 + \gamma_1)$$

we get

$$\theta_1 - \theta_2 = \frac{2\pi n \sqrt{G J_s J_w}}{k \sqrt{g}}\, y_1 \qquad (36)$$

This gives the "spring" of the coupling to be used in the polar diagram. The y value with which to start the new step follows the usual relation

$$\frac{Y_1}{y_1} = \frac{\sqrt{G_1 J_{s1} J_{w1}}}{\sqrt{G_2 J_{s2} J_{w2}}}$$

THE PERIOD OF SUBMARINE SHAFTING

The calculations have been made to determine the period of the shafting of United States submarine S4 to S13 and are illustrated herewith. The shafting is shown in Fig. 5. There are three cases to be investigated: First, the charging condition when the engine is driving the dynamo, the after clutch being disconnected; second, the surface condition, when the engine drives the propeller; third, the submerged condition, when the motors

drive the propeller, the forward clutch being disconnected.

The main shaft was divided into 10 steps as shown, and for each of these the values of J_w and GJ_s were calculated. In finding J_w in respect to the cranks, one-half of the reciprocating weight was used. In finding the moment of inertia of the propeller, 25 per cent was added to the calculated amount to allow for the entrained water.

In calculating GJ_s, the value of G was taken at 11,790,000.[3] To determine the value of GJ_s in respect to the cranks, a torsion experiment was made upon the actual engine shaft in its bearings. The value determined by this experiment for GJ_s was 4,620,000,000. The value of GJ_s in respect to the crank bearings is 3,940,000,000. The shaft with cranks is therefore 17.3 per cent stiffer than the plain shaft. In respect to the clutches, the value of GJ_s was decreased somewhat to allow for the effects of clearance. On each step the values of J_w, GJ_s, $\sqrt{GJ_s J_w}$ and Φ are marked; and on the breaks the ratios from right to left of $\sqrt{GJ_s J_w}$.

The closing polar diagrams for primary and secondary vibrations are shown in Figs. 7 to 11. In the charging condition for primary vibrations the period was found to be 24.7. As there are eight cylinders and therefore four impulses per revolution, the critical speed would be $24.7 \times \frac{60}{4} = 361$ r.p.m. In operation, vibrations of great violence were felt at speeds near 350 r.p.m. and these were most violent at speeds between 340 and 360 r.p.m. The period of the secondary vibrations for this condition was 38.8 and corresponds to a critical speed of 584 r.p.m., which is higher than any at which the engine was run.

In the surface condition, the primary period works out at 15.8 and corresponds to a critical speed of 237 r.p.m. The period of the secondary vibrations is 24.7 and corresponds to a critical speed of 370 r.p.m. In operation, violent vibrations were felt at speeds near 365 r.p.m.

In the submerged condition the primary vibrations work out at 17.2 per sec., so that, with a three-bladed propeller, slight vibrations might be felt at speeds near 344 r.p.m. The curves of relative amplitude of vibration for each case investigated are also shown in Fig. 5. They show the relative amplitude of vibration of different points on the same shaft and the position of the nodes.

It will be noted that the agreement between the observed and calculated critical speeds is fairly close. Due to the damping effect of friction it is to be expected that vibrations of maximum amplitude will occur at speeds slightly lower than those corresponding to the undamped period. It will also be noted that in the surface condition it is the secondary vibrations that cause trouble and not the simple primary vibrations. If the speed of the engine had been slightly higher, vibrations even of the third order might have been the important ones.

Calculations were also made to determine the effect of placing a Sperry magnetic clutch in place of the present flywheel and clutch. Compared to a section of shaft, the flexibility of one of these clutches is very great and it would have a profound effect on vibration. It was determined that in the charging condition the primary critical speed would be reduced to 80 r.p.m. and the secondary critical speed to 448 r.p.m. In the surface condition, both primary and secondary critical speeds would be less than 80 r.p.m., and the third critical speed would be 449 r.p.m. Thus it so happens that in this case the use of such a clutch would eliminate vibration, because the critical speeds are not within the range of the engine. The clutch has not yet been constructed and so the figures given have not been checked on the actual engine.

[3]See the *Journal of the American Society of Naval Engineers*, vol. XIV, p. 731.

The Discussion

N. W. Akimoff:—The subject of torsional vibration in crankshafts can conveniently be subdivided into two chapters, one dealing with its cause and the other with the nature of such vibration. The first has been fully covered by F. W. Lanchester in his paper on Engine Balancing, presented before the Institution of Automobile Engineers in London in 1913. The second we are now trying to settle among ourselves.

In considering the impulses causing torsional vibration, it is quite immaterial whether the shaft is rigid or flimsy. The elasticity of the shaft will be dealt with later on. The impulses acting upon a shaft are of a triple nature and include those due to explosions, to inertia forces and to octave forces. The effect of compression is included in that of explosion, since they occur with the same frequency. The following are quotations from Mr. Lanchester's article:

> The piston of a one-cylinder engine has two positions per revolution when its kinetic energy is zero, and two positions when its kinetic energy is at a maximum. This indicates that for a quadrant, roughly speaking, after crossing the in or out center, the crankshaft is doing work on the piston, and for the succeeding quadrant to the next center the piston is giving up its energy and doing work on the crankshaft
>
> The torque applied to the crank of the engine and acting on the piston through the connecting-rod involves an equal and opposite torque applied to the engine bed or frame from without. Thus, the crankshaft torque can be regarded as acting directly on the frame of the engine and undergoing two reversals per revolution. Such an intermittent torque is evidently a potential cause of vibration
>
> The torque intermittences due to compression, and explosion, and those due to piston inertia are in practice superposed, and the algebraic sum of the two, which is their resultant, is that which acts on the engine bed. Over certain positions of the stroke and at certain speeds these torques may, to some extent, neutralize one another. The torques due to compression and those due to piston inertia follow different laws; whereas, the former are approximately constant in relation to engine speed, the latter vary as the square of the number of revolutions per minute.
>
> When we add the question of the explosion pressures, we are, in effect, augmenting the torque during the expansion stroke to the extent of some four or five times; that is, an increase of the torque acting on the crank and flywheel in the direction of rotation and on the frame of the engine in the contrary direction. Here we have the recoil, or kick, so well known in the case of single-cylinder engines as the cause of a most disagreeable vibration. Its effect is felt also in multi-cylinder engines, in what is frequently referred to as the "pick-up" vibration
>
> Torque recoil as a cause of vibration can be considered in the case of a single-cylinder engine, which we will imagine to be provided with some kind of torsion balance by which the recoil torque about its crankshaft axis can be measured or recorded. We will examine a period comprising one explosion and expansion. To fix our ideas we will assume that the brake mean effective pressure in the cylinder amounts

to 100 lb. per sq. in. We will assume also, as must be approximately the case, that one-quarter of this is expended in overcoming the work done externally by the engine during the expansion stroke, thus leaving 75 lb. per sq. in. as applying an acceleration torque to the flywheel. This will represent roughly 6 ft. lb. per cu. in. of cylinder-volume energy added to the flywheel. If we know the mass and diameter of the latter, we can calculate exactly what increase of velocity this means and what additional angular momentum the flywheel has received. Angular momentum received by the flywheel means torque applied to it and, if we regard the whole engine as a self-contained system, then, since the bed and cylinder are not set in opposite rotation, a torque must have been applied to the bed of the engine sufficient in the time of the stroke to impart the calculated angular momentum to the system. This torque is, in other words, the torque required to resist the rotational recoil of the explosion. It evidently matters nothing whether the cylinder is fitted with a multiplicity of pistons or whether there is an elaboration of connecting-rod or link-work between the pistons and the crankshaft. There is a fundamental principle at stake and, as long as energy is stored in the flywheel at each explosion by a torque applied directly or indirectly from the engine cylinder, the equal and opposite torque must be borne by the attachments of the engine, whether it be a foundation or the chassis of a vehicle.

Any natural vibration period in the engine structure may pick up the main piston period, or the octave piston period, or even one of the higher harmonics of the piston motion. In some cases the impulse period may be the existing cause, so that synchronization may take place at several different running speeds of the engine.

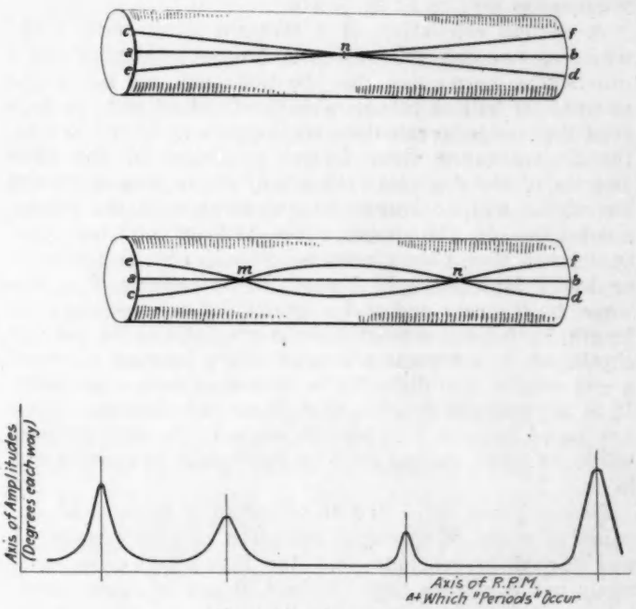
By far the greatest trouble in multi-cylinder engines is on the score of torsional vibrations and, in particular, crankshaft torsion. It is difficult to deal with the question of crankshaft torsion solely by giving greater stiffness to the offending member, and the difficulty becomes greater as the stroke-bore ratio is increased. From a rotational point of view these vibrations will not be communicated to anything without. In the case of the crankshaft, however, where the pistons form one of the vibrating masses, the vibrations are communicated to the frame of the engine by virtue of the restraint exercised by the cylinders and the connecting-rod reactions during the vibratory motion, and so the crankshaft vibrations make themselves powerfully felt on the framework of the engine and its mountings.

The main exciting causes of crankshaft torsional vibration are to be found in the torque variations due to inertia and to cylinder pressure. The first would manifest itself when the revolution speed of the engine is one-half the natural complete torsional period of the crankshaft; that is, the time of one revolution of the crankshaft is equal to two complete vibration periods of the crank in torsion, that the torque reversal takes of energy between the flywheel and the piston mass. The second exciting cause in a six-cylinder engine, and it is here that torsional vibrations give the most trouble, occurs three times per revolution; that is, there are three explosion impulses per revolution. Thus, the synchronous vibrations will take place when one revolution of the engine corresponds to three complete periods of the crank in torsion. We can consequently expect, in cases of torsional vibration, to have two marked threshing points having a speed relation of 2 to 3. The lower of these points will be that consequent on cylinder pressure; the higher will be that due to piston inertia. It is a common experience of designers who have been troubled with six-cylinder-engine vibrations to have had two marked periods of the character mentioned.

Beyond the above, it will be found on more closely examining the problem that there is a torsional vibration due to the octave component of the piston motion, which we can expect to give a synchronous revolution speed one-half that of the main inertia torsion. If, for example, the threshing point due to the explosion torque be located at 1000 r.p.m., there will be a bad threshing due to the main piston inertia at 1500 r.p.m., and the minor threshing point, due to the octave-component piston-inertia, at 750 r.p.m. Groups of this character are commonly met.

I have made these quotations because any attempt to present the matter in a clearer or shorter manner would be futile.

Considering the crankshaft as an elastic body, it is clear from the preceding statements that, even if the crankshaft were a rigid body, torsional vibrations would



FIGS. 12, 13 AND 14

still be felt by the engine and transmitted to the frame. However, a shaft is a very elastic body. If any of the impulses just described are in step with any of its natural periods, we have what is known as synchronism and the whole phenomenon is greatly magnified in effect. This second chapter can be split most conveniently into three parts: What the torsional "periods" are and how to predict them, how to measure them in an existing engine and how to neutralize them or at least how to reduce their effect.

A straight rod, assuming that one is strong enough to twist it about its axis, when let go, would vibrate in the manner shown in Fig. 12. Any straight line marked on its surface, such as *ab*, would vibrate between the extreme positions *cd* and *ef*, the extent or amplitude depending only upon the initial twist given to the rod, and gradually decreasing owing to resistance of various kinds. In the middle there would be a neutral point *n*, and that whole section, called the node, would remain at rest throughout the experiment. This would be the slowest torsional vibration possible of a straight rod and it is called the fundamental node.

This same rod could be made to vibrate in a different manner, as shown in Fig. 13. Here there would be two nodes, *m* and *n*, and any straight line *ab* originally marked on the rod would oscillate between two extreme

positions *cd* and *ef*. Here the middle section always vibrates in opposition to the end sections, which work in unison. The frequency of this vibration would be just twice that of the fundamental. This node is known as the octave, or first harmonic. To reproduce this in an experiment, the sections *m* and *n* should be held and the middle portion torsionally excited in opposition to the two extreme quarters. The same rod can be made to vibrate with three, four or more nodes, which would mean frequencies three, four or more times as great as that of the fundamental tone. As a matter of fact, any arbitrary excitation will result in a mixture of all these tones, and any external torsional effort in step with any one of these tones will raise the torsional amplitude of the latter, making it louder, while the other tones may remain quite undisturbed. At any rate the series of frequencies will be 1: 2: 3: etc.

A system consisting of a straight shaft with a flywheel on one end will possess a fundamental tone and a number of harmonics, but the node will not be in the middle. It will be rather near the flywheel and, while it is still possible to calculate the periods as in my article, the Dynamics of Gear Drive, published in the 1919 *Journal of the American Society of Naval Engineers*, the harmonics will no longer be connected with the fundamental tone by the simple series 1: 2: 3: etc. but must be derived from a certain transcendental equation of more or less complexity. If a shaft is provided with a flywheel on the rear end and a number of masses along its length, each mass consisting of a crankpin and a pair of cheeks as in a typical six-throw seven-bearing shaft of a gas engine, the difficulty is increased very materially. It is my earnest opinion that these calculations, which are based upon a number of unavoidable assumptions, would be quite useless even if they could be carried out in full.

Several years ago I had an opportunity to make an exhaustive study of torsional vibration of crankshafts. I was forced to conclude that the investigation is positively not worth its cost. Indeed, in actual experimenting we find a period practically anywhere we want it to be. The discussion then centers on the explanation of the nicety of agreement of the result with the would-be theory and the main problem, that of taking care of its effect, almost drops out of sight. In the November, 1919, *Journal of the American Society of Naval Engineers*, a paper on this subject by Prof. F. M. Lewis appears. It is most interesting from a theoretical standpoint; but I maintain my view that in complicated matters of this sort we should not waste too much time on predicting the periods but should concentrate upon handling the situation as it stands. What are the revolutions per minute corresponding to the periods that give us trouble, regardless of how closely they agree with the calculated values? How great are the amplitudes of oscillation and what is to be done about it? These are the fundamental questions. I thus submit that the torsional periods and how to predict them should be dismissed from further consideration.

Regarding the matter of how to determine the periods in an actual engine and how to find the corresponding amplitudes of swing, the greatest amplitude will determine the corresponding period. Actually, the synchronism should mean infinite amplitude, but in practice this never takes place and the conditions will be found as represented in Fig. 14. As a rule, very crude means are being used for these investigations. Sometimes one goes merely by touch and by the noise. I was told recently that thermometers, fitted in the bearing-caps, have been used as means of finding the periods. This does not appear to be a very refined or reliable method. In the absence of some device designed for the purpose of indicating the amplitude of torsional oscillation of any part of the shaft while in rotation, under various conditions as regards speed and load, such as the strephoscope, we are merely wasting time and power in all our experiments and cannot very well get down to anything definite.

In reference to remedying existing trouble in an actual engine, evidently this can be done only by putting something on this or that part of the existing shaft. We cannot strengthen it or make it stiffer in any way imaginable. We cannot change the speed and maintain the power by raising the mean effective pressure, because this usually leads to thermal trouble and also to much change in that member which is supposed to be driven by the vibrating shaft. In this connection, Mr. Lanchester's vibration damper is a very striking illustration of what can be done if one starts out from rational premises. The device is ingenious, although its action does not appear to be very well understood. Indeed, some engineers seem to attribute to it qualities that Mr. Lanchester himself never meant it to possess. A few patents covering would-be improvements of this damper, issued in this country, clearly indicate that its nature is a mystery to the patentees. My only objection to the damper lies in the fact that it operates by friction. Friction means wear and wear means necessity for adjustment, preferably by experts, and they are scarce. My opinion is that this damper was never meant for large slow-speed engines, of the Diesel Submarine type, for instance, but was designed primarily for automobile engines, where it certainly can and does help. For larger engines, my opinion is that some other type of non-frictional device should be designed. I, myself, have one design of this character, but it is not unlikely that many other types can be suggested by those who might take the trouble to look into the matter from a rational viewpoint.

In summarizing the situation, I feel that much good has been accomplished in clearing up the problem as has been done by Mr. Lanchester. One usually felt that the main harm of torsional vibrations lay in chewing up the timing-gears and in straining the shaft. It has, however, been shown in addition that torsional vibrations lead to vibrations of the engine in general and that these are of the same kind as those of unbalance or faulty design. I believe that all methods for predicting "periods" are useless. In studying the matter, we ought to pay more attention to quantitative elements in the tests. New designs should be worked out for devices by which the troublesome "periods" can be eliminated. The matter is of great importance. Possibly, prizes, medals or honors, of some suitable nature should be brought into play, to encourage engineers to suggest various remedies for the trouble.

D. G. Roos:—I have investigated the problems of crankshaft vibration for many years. During the past three years we have made some very practical and illuminating experiments. We have not gone into the analysis very deeply in a mathematical way, because the problem necessarily was to take care of engines already designed. The investigation had to be conducted in a practical way for commercial reasons.

In the seven-bearing crankshaft, we found that the difficulty was caused by torsional vibration. This phenomenon caused backlash in the timing-gears very

shortly after they were fitted. The problem of how to care for the torsional vibration was then considered. We found that Mr. Lanchester gave a clear explanation of the phenomenon and therefore thoroughly investigated dampers. Our experience was exactly the same as was described by Mr. Fox. The first type of damper he mentioned presented the same defects to us. We found it was rather sensitive to adjustment and we abandoned that type. We did not make the multiple-disc type because we had already had experience with multiple-disc clutches and had deduced from their behavior that we would have trouble with a damper of that kind. Investigations of work done abroad along similar lines showed that such was the case and that this type of damper was not satisfactory. We are now working with the type of damper which has been illustrated at this meeting.

Our next investigation was to determine what influence the weight of reciprocating parts have on the torsional vibration of the crankshaft. We found that there are three critical speeds, the worst being near 1250 r.p.m., and that they could be almost entirely eliminated by the use of aluminum pistons, with no other change. We found also that the first period, at 800 r.p.m., was made more marked by the use of two sparks per cylinder, on more compression. This appeared as a violent gear slam.

The next investigation was to ascertain what effect the diameter of the crankshaft bearings has upon the amplitude and frequency. We found that by increasing the diameter of the bearings the period was raised and the amplitude decreased to such a degree that it became almost negligible. But because of the great range in engine speeds used in automobile work, it still is necessary to retain the damper to obtain perfect smoothness.

One aspect of the problem that we have been most interested in investigating has been the influence of the number of bearings and counterweighting on torsional vibration. We have even built two engines exactly alike, except that one had seven bearings and the other four. We have experimented with both these engines, with and without counterweights. Our experience with counterweights was very interesting.

With the engine having seven bearings, the crankshaft was balanced so that it was in perfect static and running equilibrium. The counterweights were then added and the shaft was again balanced by only touching the counterweights; so, we had a shaft that was in perfect balance either with or without the counterweights. We then made a series of tests on the block, with and without the counterweights. In view of the claims made for counterweights, we were astonished to find that the critical speeds were lowered and were much more violent. We stripped the timing-gears in one engine within a few seconds after reaching the critical speed. We found that there was no increase in horsepower, but that it was lowered considerably at three points on the horsepower curve. We removed the counterweights. The engine ran more smoothly and there was no gear slam at any speed. The torque curve was uniform throughout, with no bad breaks at the points where the critical speeds showed before.

The same experiments were conducted on the engine having a four-bearing shaft. In this case we found that we had several critical speeds very badly blurred and that they came close together. Putting counterweights on this shaft made it very much worse than when counterweights were put on the seven-bearing shaft. The periods were lower and much more violent. We found also that a vibration damper installed on the four-bearing shaft would not cure the trouble. Apparently, the vibrations which occur in the four-bearing shaft, although of a torsional nature, are of such a number of frequencies that it is impossible to secure an adjustment of the damper that will care for all of them. It is possible to get them nearly all wiped out, but we find that the adjustment of the damper is so sensitive that the slightest change in the setting will cause the periods to reappear. Strangely enough, they change in frequency with the damper adjustment. The periods do not remain at one fixed point. The critical point can be followed up and down the range of engine speed with the damper adjustment. On the other hand, with the seven-bearing shaft, the vibration damper effectively cares for the torsional vibrations and is not sensitive to the setting.

I am much interested in Mr. Lewis' opinion regarding the manner in which a shaft vibrates, where there are what we might term "flying cheeks" between the bearings. We have noticed that many engines are troubled by torsional vibration and we believe that this is due to the use of too few bearings. Engineers in Europe who are building cars in which careful consideration is given to this subject, are all using seven bearings for six-cylinder engines. I have seen one engine in which the main bearings of the seven-bearing shaft were nearly 4 in. in diameter and they were bored out until the walls were less than ¾-in. thick. They were nothing more than tubes. This engine showed no critical speed, within its working range.

PROF. F. M. LEWIS:—In a straight plain shaft the critical speed would not be affected by the number of bearings, but when a complicated structure like a shaft with cranks is twisted, it deforms in a manner that makes the twist a maximum. The greater the number of bearings provided, the greater the restraint is and the less the twist. It thus would be expected that with a seven-bearing shaft, since it is stiffer, the critical speed of torsional vibration would be slightly higher. Is that the result you found?

MR. ROOS:—We found that the shafts that had a flying cheek, four or three bearings, vibrated at a lower speed and more violently.

PROFESSOR LEWIS:—That is the conclusion we reached. It is interesting because it shows the way the cheeks twisted around the shaft.

H. M. CRANE:—No one who works with six-cylinder engines can have failed to have experience along this line. Practically all that we have done coincides with what has been described. The angle that we took, however, was rather different. We decided that the safest and best way is to use an excessively large shaft. In 1912 we used a shaft 2¾ in. in diameter for a 4⅜-in. cylinder. In a seven-bearing shaft, that will give an almost impossibly heavy engine. We concluded that the shaft was big enough and could operate well enough with three bearings; so, we designed it accordingly. That job has periods that can be picked up if one is adept in looking for them, but they are so minor and are so mixed with possible slight vibrations due to bending that, to anyone driving the car, they are of no account. In any case, they are far less noticeable than periods that occur in the drive-shafts. These are matters that have not been discussed very much, but they typify problems existing in practically every car that is

built today. After we had noticed them clearly in some of our cars, I drove two rather small foreign cars, late in 1915. One had an extremely marked torsional period in the drive-shafts at from 28 to 30 m.p.h. This can be improved also by slipping clutches or by introducing some flexibility into the drive-shafts, as is accomplished by the fabric type of universal-joint.

To discourage those who are opposed to the six-cylinder engine, we built a four-cylinder 4 x 5-in. engine about three years ago that had a crankshaft 1⅞ in. in diameter, which is fairly heavy for an engine of that size. We hopefully thought that we would then be able to use timing-gears again and make them quiet enough. We succeeded in doing this but that engine had the worst periods that I have ever observed in any of our cars. They were so severe that the engine was impossible as a commercial commodity. The noise from the gears was excessive but the periods were small enough so that apparently the gears were not injured. The engine has been run many thousands of miles and has shown no excessive wear, but the noise and the feeling of it were very unpleasant. The same engine with timing chains is quiet enough and the vibration is not great enough to be noticeable when driving. Possibly, the reason this period was so strong was that we were getting greater efficiency from the engine. We were reaching mean effective pressures near 100 lb. per sq. in., especially at the lower or 1200-r.p.m. period, while our previous engines had run in the neighborhood of 90 lb. per sq. in. mean effective pressure, and with probably not by any means as sharp a card.

On the first car in which difficulty with the period in the drive-shafts was experienced, we helped the condition very materially by making the flywheel heavier. This undoubtedly moved the period enough to get it out of the way at that time, but that was not a cure, because another car with much the same characteristics promptly redeveloped the trouble, which we have finally taken out by the use of the damper. Whether by luck or not, but largely because it was the easiest way to make it, this damper was made with all the characteristics of a good damper. In other words, a flywheel was floated on the housing forward of the differential and clamped between the flange on the differential on the one side and a pressure plate on the other. There were no loose parts to rattle or wear out and give trouble. With reasonably good adjustment this wiped out the period trouble entirely, but of course the device was heavy. One could tell from the feel of the car that the period was still there; but it did not rattle the universal-joints as would be the case with no damper.

F. S. DUESENBERG:—We have worked mostly on four and eight-cylinder engines. It has been our practice to use an extra-heavy shaft,in some cases counterbalanced. We have used aluminum pistons almost entirely on both marine and automobile engines. In the case of marine engines, we have built several sizes, generally of the eight-cylinder type with five-bearing crankshafts, and with about 6¾-in. bore. We used a 3-in. shaft. None of these engines, however, were counterbalanced. The eight-cylinder engine developed some vibration at betwen 1500 and 1600 r.p.m. and there was a vibration period of between 80 and 90, but I believe that by fitting extremely light moving parts and making the shaft heavy enough the vibration period in nearly every engine can be eliminated at least to the point where it is not objectionable.

On some of the new racing engines that we have been building we have added counterweights and this necessarily makes a very heavy shaft. By keeping the cylinders extremely close together and using very few bearings, we had better results than by having a long engine with more bearings. I believe in making a very heavy shaft so that when the high speeds are reached the impulses will not have a tendency to bend and distort it. In that way we will, I think, overcome almost entirely the vibrations at the higher speeds. The small engines we are running now at speeds as great as 3500 and 3600 r.p.m., do not show any more vibration than they do when running at 800 to 900 r.p.m. In fact, they run very much more smoothly ordinarily. We have had no trouble whatever with vibration periods between 1500 and 3200.

F. C. GOLDSMITH:—About 11 or 12 years ago while I was connected with one of the pioneer automobile manufacturing companies, the chief engineer conceived the idea of putting an auxiliary flywheel on the front end of the crankshaft. That was in the days of small crankpins. The crankshaft was of the four-throw three-bearing type. The flywheel on the front end was about one-half or two-thirds as large as the main flywheel. We broke crank after crank. The minute we took off the front flywheel our troubles were over.

LIEUT. COM. W. H. PASHLEY:—We had the same sort of experience with our Diesel engine shaft, which is over 23 ft. long. At the works of a certain firm building the same type of engine in a 600-hp. size, having a 7-in. crankshaft, they contemplated putting a flywheel such as was described on the front end of the engine and securing it solidly to the shaft. They talked it over with us and we advised against it, because the twist in the shaft must be absorbed. We told them that the solid flywheel would store up the energy of the twist and that something would break, probably at the flywheel or near it. Nevertheless, they keyed a flange to the forward end of the crankshaft and secured to it a 2000-lb. flywheel. This flywheel was secured by body-bound bolts. I have no information showing how long the engine ran, but the next time I heard of it a piece of this 7-in. shaft was sent to me for examination by our metallurgist. Since then solid flywheel dampers have not, I think, been tried on Government marine oil engines.

A. L. CLAYDEN:—In justice to Mr. Lanchester, so far as I know he never suggested the damper as anything but a means for overcoming mistake in design. That was the beginning. Lately, one or two English companies have continued using it, working on the assumption that, by using the damper and designing a crank which they knew was somewhat weak otherwise, they would be enabled to cut down other dimensions and, in their opinion, obtain a better average of what they wanted. This is purely a matter of opinion but it is worth mentioning.

A. M. WOLF:—I believe that the method of driving the camshaft and accessories from the flywheel end of an engine should not be overlooked merely because it seems on the surface to offer difficulties in the repair shop. A further analysis should be made. In the design of any machine, reliability and accessibility go hand in hand but in an inverse ratio. The more reliable a unit or part may be, the less need there is for its being accessible, and vice versa. Because we have gear trouble, we provide utmost access to the gears. This trouble is due to torsional vibration. Is it not folly to drive off a crankshaft at the "loop," at the relatively light free end, instead of at or near the node? With the latter drive our present gear trouble will cease to a large extent. I fail to see why, by driving at the flywheel end where the

angular velocity is constant for all practical purposes, a set of properly-proportioned gears should not have a sufficient life to require no looking after until the thorough overhaul. With reliable gears we do not need the present accessibility.

To provide a camshaft drive from the flywheel end offers no difficulties that I can see, so long as it is made amply accessible. It is purely a matter of design. Of course, we must not put a radiator back of the cylinders or attempt to crowd a steering-gear over the drive housing. Driving a camshaft and some of the auxiliaries is anything but a constant load; it is very intermittent. Such a condition makes a very poor combination with the oscillations of the crankshaft gear due to torsional vibration. A flywheel at the forward end of the crankshaft is desirable only with a constant load and speed.

The use of a damper does not entirely eliminate the vibration, as some slipping must occur or the damper would not serve its purpose but act as a flywheel keyed to the shaft; therefore, with a damper there is still possible a slight chattering between the gears, if they are located adjacent to it. I feel certain that, particularly in the case of the large Diesel engines described, driving near the node is bound to come into practice and is the only logical solution of some of our gear trouble when dampers are not used.

E. FAVARY:—In regard to the experiments mentioned by Mr. Roos, it is interesting to know that additional counterweights increased the vibrations, but let us not condemn counterweights in general because certain results were obtained in that particular engine. Mr. Lanchester's paper mentions various kinds of vibrations apart from torsional vibrations, for instance, those due to the inertia of the reciprocating parts when they are in synchronism with the vibration period of a structural portion of the engine on the chassis used in the motor car. I therefore believe it possible that sometimes, by using counterweights, we might get a new order of vibrations due to the new vibration period arising from the use of such weights being in resonance with some of the harmonics in the engine structure. I suggest that we do not condemn counterweights outright, for we know that better results have been obtained by their use, in a number of instances. It is a subject for further investigation.

L. G. NILSON:—It is possible that in the past counterweighting has been overdone. In the early days at least, a counterweight was considered purely from the standpoint of balancing the reciprocating parts; that is, the counterweight was made about equal to the combined weight of the piston and connecting-rod. This would balance the engine in a direction parallel to the motion of the piston, but would set up a disturbance 90 deg. from that direction that was very noticeable in a single-cylinder engine. Still, it would be almost impossible to get satisfactory service from a single-cylinder engine without counterweights. In a four-cylinder engine having a stiff crankcase, heavy crankshaft and large bearings, the disturbance of the counterweights will hardly be noticeable because the outer weights are balanced against the center weights, just as the end pistons are balanced against the middle ones. I believe in moderate counterweights, something like those used in the Darracq engine of 10 years ago, in which the webs of the cranks were extended equal distances on each side of the main bearings. These engines were, as we know, smooth-running.

Mr. Crane has pointed out that we have torsional vibrations in perfectly straight shafts when running them at high speeds. If these vibrations remained purely torsional, as illustrated by Prof. Lewis' twisting wire supporting the weight at its end, they would do no harm; but, when running at high speed, the impulses from the explosion in the cylinders transmitted to the various crankpins produce a bending of the crankshaft and possibly a distortion of the crankcase itself. This bending, together with the torsional spring of the shaft itself, sets up a sort of whipping action, which, when it happens to harmonize with the natural vibration of the shaft or its supporting framework, will multiply itself into violent disturbances.

The remedy is, I should say, a rigid crankshaft, a rigid crankcase and bearings that are as large as possible. We all know that it is necessary to have some clearance in the bearings. The film of lubricating oil must be thick enough to keep journals and bearings apart, in a machine of long life. With bearings that are too small, the film of oil is squeezed out. This necessarily bends the crankshaft slightly, thus starting not only torsional but also lateral vibration. If the bearings are large enough, we not only have the benefit of a more rigid crankshaft but, when running at a high speed, the duration of the explosion will not allow time enough to squeeze out the oil film. If we once understand the problem thoroughly and the reason why these things happen, it is not only better business but often easier to prevent the trouble by eliminating the cause, rather than to find a later remedy.

M. C. HORINE:—Has anyone thought of using springs instead of friction in the Lanchester vibration damper? It has been brought out that where a vibration damper is used energy is consumed and heat produced; that means wear and waste of power. I believe the Lanchester damper does consume power. Might not the damper be made with springs so that the absorption of power from the shaft would result in compression of the springs, and the overtaking of the shaft by the flywheel give that energy back to the shaft? I think much of the absorption of vibration is due, as was suggested, to having one period damped out by another.

A bad case of vibration occurred last year in the Snead Iron Works. A large stationary engine there rocked the building so that nobody could work in the office. An expert on vibration told them to put a big flagstaff on the building, equip it with a heavy iron collar controlled by pulley ropes and slide it up and down the pole until they found a point where the vibration stopped. They took him seriously and did this and when they found that particular spot the vibration stopped. When starting and when shutting down the engine there was vibration, but when the engine was running there was none. The explanation is simply that the weight on the flagpole produced a pronounced period of vibration which was in direct opposition to that of the engine, so that each damped out the other.

In considering torsional vibration of crankshafts we should not forget other vibrations in the chassis. The horizontal opposed engine, although it may not balance the shaft against torsional vibration, does balance the engine as a whole against the reaction of the cylinders from the combustion and is worth considering from that standpoint. Of course, the reason we do not use opposed engines is that they do not fit the chassis.

As to why we do not drive the camshaft from the rear end of the engine, my experience in a repair shop makes this clear to me. I do not favor the idea of coun-

terweights on the crankshaft. I have worked on a certain make of six-cylinder four-cycle engine which has its crankcase literally filled up with counterweights and it is difficult to get at. Regarding the four-cylinder 4 x 5-in. engine with a 1⅞-in. crankshaft, which Mr. Crane characterized as a large shaft for that size of engine, the company I represent has built for a number of years a 4 x 5-in. engine with a 3-in. crankshaft. It is a slow-speed engine, as truck engines usually are. We do not know what vibration that engine has. We govern it at 1250 r.p.m. and, up to that point, we get no vibration. A characteristic slow-speed engine, when running very slow, sometimes rocks the chassis. We build that same type of engine in a 5 x 6-in. size and with the same size of shaft, for fire apparatus. We run it at considerably higher speeds to get more power. Those engines use the crankshaft with a slightly different timing and aluminum pistons. We get no objectionable vibration in them up to more than 2000 r.p.m. Bear in mind that these are slow-speed engines. We have also some experimental engines of various types, one of which has a 3½-in. crankshaft and a 3½-in. bore.

Many people object to a large crankshaft because of its weight, but I have always believed that a tube is stiffer than a shaft containing the same amount of material. It is certainly as strong for all practical purposes. We simply bored it out in this large shaft of ours, and it works very well. I do not know how fast we have run that engine without vibration, but I do know from the amount of power we have gotten out of it that it must have run well over 1250 r.p.m. This leads me to believe that there is some merit in large shafts and that they need not be heavy.

MR. ROOS:—I do not wish my remarks interpreted as condemning counterweights. I am merely citing our experience. If there is any new way of attaching counterweights, I would like to know of it. We have tried every combination that had any reasonable basis and reached a point where we concluded the weights have no value. We tried eight and then four weights on our four-bearing shaft. We found that it behaved nearly the same with four weights as with eight. Another manufacturing company made a similar set of experiments, came to the same conclusion and left off the counterweights. I have talked with well-known engineers who also have made experiments and who decided it would be better to leave off the counterweights.

In regard to the Lanchester vibration damper, I think it is no reflection on its merits that it was invented and used to remedy a defect in an existing engine. Great discoveries are sometimes made in that way. We believe that the Lanchester damper enables us to design crankshafts that are more rational than if it were not used. It is very desirable to reduce the diameters of the pins and bearings for structural reasons. With high rubbing speeds in the bearings, due to large diameters, it becomes a problem to support the main journals. I agree that the 4-in. bearing I described is extreme. If the designer of that engine had used the Lanchester damper, he would have used a much smaller shaft.

So far as the six-cylinder engine is concerned, the problem of torsional vibration is solved satisfactorily by using a crankshaft having seven bearings, preferably, and a damper. The vibration damper has been developed to a point where it gives little or no trouble. I fail to understand why we should consider torsional vibration as a serious problem any longer. The damper is expensive and possibly is not available for use if a car must be manufactured within certain cost limits, but I am convinced that, combined with a properly-designed crankshaft, it has been demonstrated as a satisfactory solution.

LIEUT.-COM. PASHLEY.—In connection with the suggestion that springs might be used instead of friction, I had a design submitted to me which was called an oscillating-weight-type damper. There were springs between oscillating weights swung on pins secured to a flange on the shaft. We concluded that this damper would have a period of its own, due to the recoil and compression of the springs; also, that instead of avoiding the trouble, the oscillation of this damper might coincide with the oscillations of the crankshaft, giving a twist as bad or worse than we already had.

J. F. FOX:—I think the damper does offer a solution to the problem of torsional vibration. Mr. Roos gave an interesting account of following the periods up and down the length of the operating range of the engine. We had that same experience with the first type of damper. We tried various settings with that damper, and we still had vibration at some speed. The problem seems to be to get a damper that has a soft, easy action. It must not grab and let go at the beginning and end of each vibration; it must have an easy action and, to obtain this, plenty of area must be allowed for the friction surfaces. The multiple-disc type of damper has this soft easy action and that is why we used it. The damper worked all right, as we thought it would, but it developed the defect that I have explained. We then used the other damper with the larger area and the engine has been run 36 hr. without any change whatever in adjustment of the damper.

PROFESSOR LEWIS:—In regard to Mr. Akimoff's criticism of the illustration I used, that was just an elementary example to show what the subject is about. When I first took up this question and tried to devise a method for calculating critical speeds, I naturally went through all the literature I could obtain. I did not seem to advance very far, but after a time I found it was possible to get a practical solution that was quite simple.

The question of balance has been brought up several times during this discussion. The question of torsional vibration is quite apart from the question of balance. They are two entirely different questions; a thing that will affect balance might have no effect upon torsional vibration. The opposed cylinder is really a question of balance, and not one of torsional vibration. Also, the question of the other kind of vibrations that might occur in the engine, the vibrations of the chassis for instance, is apart from the question of torsional vibration. It is impossible to make any general rule for eliminating vibrations. It may be a change or an increase of shaft in one case, and in another case it may be a decrease, or perhaps a change of weights. In general, if one is working with a shaft that vibrates badly, an increase in the size of the shaft would tend to eliminate vibration. As to driving the camshaft from the node, that is of course desirable, but is practically impossible. The question of a spring damper also occurred to me and I reached the same conclusion as that of Lieut.-Commander Pashley, that there would be fully as much danger of increasing vibrations as of decreasing them.

I do not claim that a method for calculating the critical speeds of torsional vibration will in itself remedy all trouble in existing engines. An analysis of an engine may, however, throw such light upon its defects as to enable us to correct them with intelligence and direct-

ness. The primary object of a method for calculating critical speeds is to enable us to avoid this serious trouble in future construction. It is possible to determine while the engine is still on paper, by the method given, whether trouble is to be expected from torsional vibration and thus, by properly modifying the design, to avoid that trouble. As Mr. Akimoff has himself put much effort into an ineffectual attempt to devise such a method of calculation and has published an article giving a method suitable to certain simple cases, he evidently does not consider such a method as useless as he would have us believe. The calculations in the case of the submarine engines have been illustrated. If these engines had been designed with a shaft only ¾-in. greater in diameter, all trouble from torsional vibration would have been avoided and many thousands of dollars saved. The magnetic clutch mentioned in the later part of the paper has since been constructed and tested and its actual and calculated performances found to be in close agreement.

THE SUBGRADE OF HIGHWAYS

THE practice of designing uniform construction for all parts of a road, regardless of differences in soils, is the source of many failures in roads. Engineers who have studied the subject intelligently agree that most of the failures of brick highways have been due to defective subgrades. Experiments have demonstrated that an 8-in. slab, 4 in. of vitrified brick and 4 in. of concrete foundation united in a monolithic beam, if properly built will sustain almost any traffic load if the supporting subgrade be stable and uniform.

Drainage is highly important. Too much stress cannot be laid on that point. But drainage alone, as it is now done by almost uniform specifications, will not suffice. It is difficult in any case to prevent moisture from entering a subgrade, either from capillary action or by seepage; but different soils require different treatment. It is of the utmost importance to know the soil and to know how it acts under the influence of different degrees of moisture content.

Very few highways have uniform soil conditions. There may be gravel that drains readily, and sand that compacts easily, and sand that refuses to compact, and clay that retains moisture persistently, and quicksand that when saturated is as unstable as quicksilver.

Very frequently all these conditions are found on a single road. It is therefore manifestly absurd to design a uniform slab for such a road. On some portions of the road a 7-in. beam would suffice for any traffic. On other sections of the road a 12-in. beam might be required, while on the worst sections heavy reinforcement might be necessary. Nor would the question of drainage be less complex. Instead of emphasizing building roads for the traffic, better results will be obtained by building roads for the soil. If we do that, the traffic problem will solve itself. This, of course, presupposes the building of a high-class type of road that in itself has strength and wearing qualities. If there is on a road only one spot of poor soil, however short, the design should be changed to meet the conditions, and changes should be made wherever poor spots occur.

It is obvious that comparatively light construction will serve where the subgrade is dry, firm and unyielding, but that heavy construction is advisable when the nature of the subgrade makes it necessary for the beam itself to supply a large part of the load-bearing strength.

Study of the soil has been neglected in the past. In fact, soil as an integral factor in pavement construction never received serious consideration until the war brought heavy trucking over highways into the problem, and it is only very recently that soil study in relation to road building has been taken up in the spirit of scientific inquiry.

The United States Bureau of Public Roads, the Federal Highway Council, State highway departments and other bodies have at last undertaken research work with a view to acquiring accurate data regarding soils, as a basis for scientific road building. The Bureau of Public Roads has done some field investigating, making borings where high-class road surfacings have broken down, and conducting laboratory analyses of the different soil specimens which have thus been obtained.

So much attention has been given in years past to improvement of road-surfacing methods that interested engineers and others have overlooked the fact that the only really permanent part of a road is that which supports the metal. Surfacings wear out in time but the grade ought to be so constructed as to remain indefinitely, serviceable for resurfacing several times. Improving a highway is a structural problem akin in principle to the erection of a lofty building. In either case the stability of the superstructure depends on the rigidity of the foundation and its natural support. Architects and builders do not figure on the same style and weight of foundation for all kinds of subsoil. Roadbuilders should be equally discriminating in the matter of foundations.—F. A. Churchill in *Engineering News-Record.*

EFFECT OF KILN DRYING ON THE STRENGTH OF WOODS

THE belief that kiln drying necessarily makes wood brash or "takes the life out of it" is discredited in report No. 68, entitled A Study of the Effect of Kiln Drying on the Strength of Airplane Woods, which was recently issued by the National Advisory Committee for Aeronautics.

This report contains the results and discussion of tests on 14 of 26 species tested at the Forest Products Laboratory, Madison, Wis., to find the effect of kiln drying on strength. The conclusions reached and test data are applicable also to woods used in the various other forms of automotive apparatus in common use.

The chief conclusions are (*a*) proper kiln drying produces material fully equal to carefully air dried stock, (*b*) through improper kiln drying wood may have its strength properties, particularly its toughness or resistance to shock, seriously damaged without visible evidence of such damage and (*c*) the effect of a given kiln drying process is not the same on all species.

Safe limits of temperature and relative humidity to be used in drying the several species are given in this report, a copy of which can be had upon request from the National Advisory Committee for Aeronautics, Washington.

OLD TRANSACTIONS AND JOURNALS WANTED

THE Society is desirous of maintaining a complete file of the TRANSACTIONS, not only for its permanent records, but also for the use of members visiting the office. At present there are no copies of the TRANSACTIONS from 1906 to 1910, inclusive, and for Part I, 1912, Part II, 1915, and Part I, 1916, in the office. Members having any of these volumes that they are willing to let the Society have are urged to communicate with the office in New York City.

If any of the members have copies of the *S. A. E. Bulletin* for which they have no further use, they will confer a favor upon the Society if they will write to the office promptly and give a list of the available copies.

CRACKING

PETROLEUM consists essentially of a mixture of hydrocarbons which are in the main totally miscible with one another. Organic nitrogen and sulphur compounds are present in varying amounts and occasionally oxygen compounds as well as water and inorganic material in diverse forms. When this complex compound of naturally occurring hydrocarbons is treated by dry distillation at atmospheric pressure the hydrocarbons of lowest boiling point are vaporized first and come into the condenser followed by those of higher boiling point as the temperature rises. Varying degrees of fractionation will obtain depending on the design of the still and the method of operation. From the point where gases first appear at the condenser outlet until the temperature in the still reaches approximately 625 deg. fahr. the products secured are in the main natural, that is, they exist in the crude oil as such. Above this temperature, especially if the distillation is carried out slowly, what is known as cracking takes place and a distillate is obtained which on redistillation will yield more gasoline and kerosene, their quality in most cases not being comparable with that of the natural products.

Instead of carrying out the distillation above the 625 point at atmospheric pressure in an ordinary still one of special design is substituted. If the operation is conducted at a pressure varying from 50 to 150 lb. profound decomposition or cracking occurs and a yield of gasoline of 15 per cent or more based on the original charge of residue can be obtained on fractionating the pressure distillate obtained. The residue remaining and the pressure distillate which has thus been freed from the gasoline can again be subjected to the process and a further yield of gasoline obtained, this being less than in the first case and decreasing on subsequent treatments.

This process of cracking is a special application of the well-known phenomenon occurring when organic compounds are heated to a high temperature, decomposition taking place and the molecule breaking down into compounds of lower molecular weight, even with the formation of the elements carbon and hydrogen. If a sample of the same residual oil be placed in a vertical still having a fractionating column or tower interposed between the still and the condenser and the distillation is carried out at atmospheric pressure, with stirring, in the presence of anhydrous aluminium chloride, the latter acts as a catalyst to cause the decomposition of the oil into gasoline, giving a yield of 15 per cent or more. This process is an illustration of the fact that chemical compounds working at atmospheric pressure may effect a result similar to pressure distillation.

The various processes for producing fuel from heavier hydrocarbons can be roughly classified as follows:

(1) Pressure still, a two-phase cracking system. Examples are the Burton and Coast processes
(2) Pipe still, generally a one-phase cracking system. Examples are the Greenstreet, Hall and Rittman processes
(3) Use of catalytic agents at atmospheric pressure. This may include reactions in both the single-phase and the two-phase systems. An example is the aluminum chloride process which is probably two-phase to some extent
(4) Combinations and modifications of two or more of the above methods; the cracking may be in either single-phase or two-phase systems. Examples are the Dubbs, Jenkins and Bacon processes
(5) Processes involving principles not included under the previous headings but which may involve similar apparatus or the use of pressure; these methods may have either single-phase or two-phase cracking systems. Examples are the proposed processes of Cherry, Coast, Ellis and many other processes equally unique. In the first a bipolar high voltage, oscillating, silent electric discharge is thrown across the vapors; in the second hot gases are passed through the oil or into contact with oil spray; and in the third air is supplied to the cracking chamber where by the combustion of a portion of the oil the heat necessary for the cracking of the remainder is generated

During the last eight years numerous patents involving almost every conceivable form of apparatus have been granted to obtain hydrocarbons within the gasoline range from those of higher boiling point. Many of these patents seek to obviate the trouble incident to coke deposition while others have the object in view of producing a gasoline which is comparable in quality with the natural product. Still others are along entirely new lines.—From paper by F. W. Padgett presented before American Society of Mechanical Engineers.

CRITICAL POINTS IN HEAT-TREATMENT OF STEEL

THE first mention of the observance of the cooling or recalescence point was made in 1869. Gore Barrett in 1873 reported the finding of the heating or decalescence point. Thus "it has been known for some time that the rate of cooling or heating does not proceed uniformly, but that at certain temperatures, which may vary with different compositions, retardation occurs. These are termed arrestation points, critical points or critical temperatures, transformation or transition points. They are caused by physical changes whereby heat is liberated on cooling and absorbed on heating."

The modern heat-treater has at his command apparatus of great precision on a variety of methods for the determination of the critical or transformation points of the steels with which he must work. He can obtain theoretically and practically the correct temperatures to which his steel must be heated in order that it can be properly annealed, hardened or otherwise treated.

The best-known methods for the determination of the critical points are the thermal, the metallographic, the calorimetric, the thermo-electric, the melting-points, the magnetic and the dilatation. Most of these methods are best applied in the laboratory with the exception of the melting-points and magnetic forms, which can easily be carried out in the plant proper. The thermal method is the one most used.

While there are many kinds of furnaces in use, all can be classified primarily as being either of the semi-automatic or continuous type, or the stationary type which also includes heating baths such as lead and the like. In the former type the work is carried through the heating chamber in some way and must acquire sufficient heat in transit to allow for proper hardening, etc., to take place. In the latter type, the work is placed in the heating chamber or bath and allowed to come up to the desired temperature as quickly as its size will allow. Given a furnace of either type, a method of temperature-indication control and critical curves of the steel to be treated, it should be comparatively easy to obtain the necessary results in heat-treatment work. Pyrometers, as generally applied to heat-treatment work, do not indicate the temperature of the steel in the furnace, but of that section of the heating chamber where the point of the thermocouple is actually located.

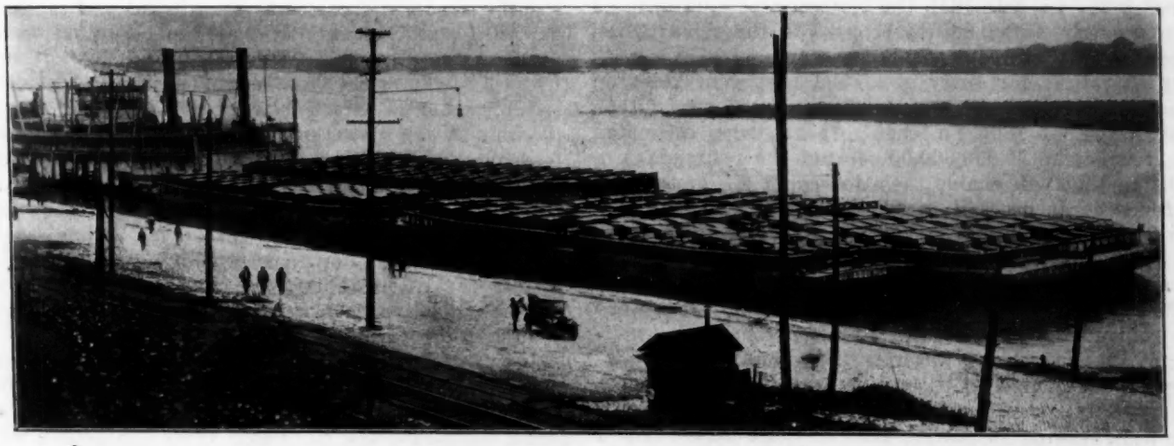
No heat-treatment can be successfully accomplished without knowledge of the four basic factors involved therein, which are time, temperature, mass and surface. Steel to be properly heat-treated must be uniformly heated throughout its entire area. The "human element" factor is very important.—From a paper by A. W. F. Green before the American Steel Treaters' Society.

Problems of Inland Waterway Transportation

By CARL J. BAER[1]

SEMI-ANNUAL MEETING PAPER *Illustrated with* PHOTOGRAPH

PRODUCTION and transportation are the problems of the hour. The two subjects are so closely interwoven in the Nation's fabric that it is useless to consider them separately. We believe the great problem of transportation can be satisfactorily solved only by the utilization of our navigable inland waterways. All other enlightened nations have resorted to water transportation to master the same problem successfully, and the time has now come when we must adopt the same course to meet the needs of our own people.



A MISSISSIPPI RIVER TOW BOAT AND SIX BARGES LADEN WITH A SHIPMENT OF 400 AUTOMOBILES

We have the greatest natural waterways known in the world, but have shamefully neglected to use them. Ours is the only important country that does not use its water highways for transportation purposes. While we have continued to refuse the benefits offered us through the possession of these great channels of commerce, other countries, which have not been blessed with such natural water channels, have spent hundreds of millions of dollars in creating artificial water routes over which to transport their products.

The United States today is facing the same problem that confronted the European nations 50 years ago, at which time they reached the conclusion that they could no longer depend upon their railways alone for the handling of their rapidly growing commerce. They then began in a practical, common-sense way to build a complete system of waterways. It cannot be successfully denied that for 100 years the important factor in the development of our American cities and towns was in a great measure the utilization of our inland waterways. A brief history of the usage of the waterways throughout the United States shows conclusively that water-borne freighting by the old steamboat method was cheaper than by the rail system. However, due to limited terminal facilities, lack of equipment for handling freight and the irregularity of service, the river carriers were finally supplanted by the railroads. The large shippers of the country became dissatisfied with boat service because boats were unable to give the shipper the advantage of store-door delivery. To overcome this dissatisfaction, the boat lines arranged to deliver the freight by wagon from the steamboat landing to the business concern served. This was done in most cases at a loss to the carrier. The irregularity of river traffic caused by floods, low water, ice and other obstacles was an added reason for the discontinuance of river transportation.

Prior to the Civil War New Orleans enjoyed the distinction of being as large a port as the City of New York. Cincinnati, Louisville, St. Louis and other inland cities on the rivers were larger and more prosperous than Cleveland, Milwaukee, Chicago, Detroit and other cities served by the Great Lakes. At that time the river cities were thrifty industrial and commercial centers, as many as 200 steamboats being often seen at the St. Louis landing. At about this time after careful investigation English and American financiers invested largely in the building of railroads through Chicago to the Northwest and West. Not until several years later was there any development of rail transportation into the South, the war-stricken country. When, however, the railroad lines were constructed to the South from Chicago, they were, in most instances, built parallel to navigable rivers and touched towns and cities already developed by the water medium.

Chicago soon became a pivotal city and a basic rate-making point, and has enjoyed this distinction ever since. After 50 years we find that Cleveland has doubled the population it had; Cincinnati, Milwaukee and Toledo have forged ahead of Louisville. Chicago has built a city three and one-half times the size of St. Louis, and New York clearly enjoys every advantage as a port over

[1]Member of the Chamber of Commerce, St. Louis.

its former rival, New Orleans, which city, on account of its geographical position, should have maintained its rank as the leading port of America. Although millions of dollars have been spent on our inland waterways, the expenditures of the railroads in two years and two months, while under Government control and during the last war, are said to have been more than the total amount of expenditures for river development in a half century. It might, therefore, be well for all of us to withhold our opinion on the probable outcome of the experiment now being made by the Government in testing out and endeavoring to provide a solution for this most important national problem.

Mississippi Waterways Association

The Mississippi Valley Waterways Association was created at the suggestion of Newton D. Baker, Secretary of War, almost immediately after our entrance into the world war. At that time the question of transportation was a serious one; he urged strongly that all means of transportation should be fully utilized. His request was to put the Mississippi River immediately into use as far as possible. In 1918-1919 the Government appropriated approximately $7,000,000 to be used in the construction of new and modern equipment. Contracts were let shortly after that time for forty new steel barges of 2000-ton capacity each, and six modern tow-boats of tunnel-type construction, of 1800 hp. each. It has been estimated that it will take $5,000,000,000 to put the railroads in a condition that will enable them to render adequate service for present necessities. It is safe to say that less than $1,000,000,000 invested in proper water transportation equipment will carry an equal amount of freight per annum.

The Mississippi Valley Waterways Association has been continually assisting the War Department in carrying out its program of water transportation. The Government was compelled to operate during the war with old tow-boats and without modern equipment. These old boats were lacking in power; none of them exceeded 600 hp., which is not sufficient to carry cargoes efficiently up-stream. The Mississippi Valley territory, which includes 26 States touching the most navigable rivers in the United States, produces 50 per cent or more of the Nation's export commerce. The 10 leading cities of this valley are the largest North American markets nearest to Central America, South America, the West Indies and Mexico, and the balance of trade with these countries is now largely against the United States. These Mississippi Valley cities enjoy geographic proximity and shorter hauls in reaching that important export trade. Any manufacturer whose raw materials are cotton, wool, copper, lead, zinc, limestone, coal, coke, fire clay, sulphur, salt or hardwood, will be closer to the sources of supply in the center of the Mississippi Valley than in any other fully developed industrial district in the United States.

Raw materials are produced in the Mississippi Valley in the proportions given in the table at the bottom of the previous column.

RAW MATERIALS PRODUCTION OF THE MISSISSIPPI VALLEY

Commodity	Per Cent of Total United States Production
Corn	85
Wheat	76
Cotton	70
Petroleum	69
Coal	60
Wool	55
Hogs	81
Cattle	74
Sheep	52
Lead	World's largest production
Zinc	World's largest production
Barytes	U. S. A. largest production
Kaolin	
Fire Clay	

Hickory, Ash, Oak, Cypress and Yellow Pine represent the largest supply in the United States.

Standard River Freight System Needed

To you members of the Society of Automotive Engineers, who so ably assisted the Nation in solving many difficult problems during the world war, let me say that its greatest call is for a similar service from you in this reconstruction period. The usage of our inland waterways is, in my opinion, 80 per cent a mechanical engineering problem. A standardized system for handling freight on inland rivers should be adopted. This system should include the standardization of boats, barges, terminals, devices for loading and unloading freight, and units for handling freight from boats to railroad and trucks. We should include in this system the coordination of all carriers operating in inland rivers, and should cooperate in every way with those engaged in the railroad and truck business. Store-delivery methods are now made possible by the motor truck and, since the coming of the internal-combustion engine and the development of the highways of America, it is now possible to effect a delivery of freight from the water carrier as economically as by the switching of the railroad car and this delivery is not limited to the owner of a railroad switch. In other words, the highway and the truck make possible the store-door delivery to every citizen in the community, including the farmer.

Shortly after the $7,000,000 appropriation was made, there was an additional appropriation of $3,600,000 for equipment to operate on the Upper Mississippi River between St. Louis and St. Paul. This equipment was designed for the purpose of carrying coal north and bringing Minnesota iron ore south, for use in the furnaces of St. Louis. This provides for 19 modern steel tow-boats of stern-wheel type of 2000 hp. each. The Government has recently appropriated $4,000,000 to be used for equipment, and to continue the operation of the boats and barges now in use. Of this amount $2,100,000 will be expended in building transfer terminals at East St. Louis, Cairo, Memphis, Vicksburg, New Orleans and Mobile. This $4,000,000 will insure the continuance of Government operations until they will have thoroughly demonstrated whether the movement on the Mississippi River will be a success or a failure.

Brigadier General Frank T. Hines, U. S. A., chief of the Transportation Service of the War Department, in an address before the annual convention of the Mississippi Valley Waterways Association, said that the Government, in inaugurating a river service between St. Louis and the Gulf, had no desire to compete with private owners whose craft ply on parts of this route. Yet if Government operations did momentarily handicap some private operators in that territory, these individual losses will certainly be repaid many times in the far-reaching benefits which river traffic as a whole must derive from these operations. It is only from such a broad viewpoint that the benefit of the present Government waterway policy can be realized and thus eventually materialize. We should lose sight, to some extent, of the words "gov-

ernment operation," and mentally replace them with "government co-operation." Then we have the spirit of the new governmental interest in waterways and can better appreciate the means and anticipate the logical results of this experiment.

If the Government succeeds in pointing out the right methods to be followed for successful waterway operation, any expenditures made to this end must necessarily redound to the good of the community and therefore be well justified. There is much difference of opinion as to the extent to which Government ownership of public utilities can be properly carried. But in this field, that of intelligent experimentation and development which seeks to point out to individual enterprise at public expense the profitable economics of waterway operation, the Government is actually performing one of the functions for which it exists.

I suggest that the Society appoint a committee of engineers to cooperate with the Mississippi Valley Waterways Association, and that the committee be empowered to meet from time to time with those who are interested in the development of the waterways of America. This will enable us to keep in close touch with the engineering talent and the automotive industry of the country, and at the same time give those concerns which you represent an opportunity to know the progress we are making. I trust your organization and its members will in every way render assistance to this movement and give to the Nation the same loyal service you rendered in helping to win the world war.

CRANKSHAFT VIBRATIONS AND CRITICAL SPEEDS

(*Concluded from page* 417)

between the teeth of the friction discs and the driving-hub is the cause of the pounding experienced.

In an effort to combine the good points of the two dampers described, the split-flywheel vibration damper shown in Fig. 14 was designed and constructed. It consists of a cylindrical case, solidly keyed to the free end of the crankshaft. Within this case is a flywheel made up of two parts pressed against the floating friction plates *s*, by means of the springs *t*. The pins *u* cause the two halves of the flywheel to rotate together. The friction plates *s* consist of a ring of ¼-in. steel boiler-plate with asbestos brake-band lining riveted on each side. These friction plates float between the flywheel and the case. Oilless graphite-spotted bushings *v* are used in the hub of the flywheel to prevent seizing on the hub *w*. The area of the friction material on this damper described is about three times that used on the first damper, and it is expected that the wear will be greatly reduced. Tests now being carried out on this damper give every indication that it will prove to be a satisfactory answer to the troubles experienced. [The discussion of this paper will be found on page 442 of this issue.]

MOTOR BOAT STANDARDIZATION

THE various economies effected by standardization are familiar to all and the power boat industry will benefit by this standardization as the automobile has benefited. The stock boat belongs to the majority, and since the so-called majority has a practical turn of mind developed by educational personal contact with tall water, sandbars, landings, leaky decks, fouled propellers and the like, it might be advisable for the amateur to consider the results of wide and practical experience before contemplating "minor changes." When a single "minor change" is insisted on by the buyer of a stock boat, he must take the consequence of defeating the sole purpose of standardization, better workmanship at lower prices. It is the production of many boats, identical in all respects, that gives the owner the advantage of quantity buying of equipment and raw material. It gives the saving in overhead charges that must result in the solving of problems in construction, for the original model has borne this alarming expense. Perhaps you may favor a certain cruiser in practically all of its essential points, but object to certain bits of deck hardware that do not seem quite what you like. It is my suggestion that you seek the representative of this boat and give him your criticism. The chances are that he will have a satisfactory and sufficient explanation why those irritating pieces of hardware are used instead of the particular kind you prefer.

In planning and ordering equipment, as well as in the development of the hull, it stands to reason that the builders have used their skill and experience to make that boat a success. Every little detail is considered and reconsidered by the boat builder to find the most suitable method. It may be the weighing of your prejudice, even your inexperience, against the wisdom of men whose reputation and livelihood are dependent on this boat. When buying a stock boat have an open mind and try to see if the builders are not right after all. It may be a blow to your individuality and pride; but remember that little ship will look differently with green water curling about than she does on her display cradle.—H. A. Patterson in *Power Boating*.

EXPERIMENT IN TELEPHONING VIA CABLE WIRE

A VERY interesting experiment is being conducted at the Army Balloon School, Fort Omaha, Neb., with a single-conductor loud talking balloon telephone which is being designed in the experimental laboratory at Fort Omaha for balloon use. All wires from the balloon to the ground, including the reel cart on the ground, are eliminated as the single conductor is the balloon cable itself.

The set is made to connect on each end of the balloon cable and connections provided for the chart room or for any standard telephone system. The telephone does not involve any of the transmitting principles of radio telegraphy and cannot be heard with wireless receiving apparatus.

Very satisfactory conversations have been carried on at an altitude of 800 m. (2620 ft.). The voice from the ground can be easily understood at a distance of from 4 to 5 ft. from a single receiver.—Air Service News Letter.

MOTORIZING THE FARM

ON Ray Graham's 1500-acre farm in Washington County, Indiana, it has been economically profitable to reduce the animal power until only one mule is required for each 67 acres and one man for each 110 acres. Mr. Graham would not set a definite date for getting rid of the mules, but did say, "just as soon as it is an economic proposition." It depends on the success of the motor cultivators which were used for the first time last season. If the enthusiastic endorsement which Mr. Sordelet, the manager of the farm, gave these machines is any criterion, the mules' days are numbered.

The mules are now used for seeding grain, cultivating corn, farm hauling, odd jobs and as auxiliaries to the tractors in soil preparation work. The tractors furnish the bulk of the power for plowing, soil preparation, harvesting, threshing, silo filling, shelling and grinding. The heavy hauling is done with a truck. There is one large tractor, the first motor equipment purchased, which will pull from 8 to 12 plows, depending upon the condition of the soil. It is used for fall plowing and belt work, but has proved to be too heavy for spring work. While used only a relatively short time during the year, the big machine is considered a good investment. "Why, it almost paid for itself last fall," said Mr. Sordelet, "when we put in 600 acres of wheat. The ground was hard, the weather hot and the time short. The only poor wheat we had was 40 acres sown late. If it had not been for that big machine we would have had 200 acres of poor wheat instead of 40 acres." The other three tractors are of the three-plow size, which is considered to be the best for general farm work.

All the harvesting is done with the tractors. If the large tractor is used, four binders are put behind it. Two are pulled by the smaller tractors. A man is put on each binder and the tractor. This method increases the man-labor requirements somewhat, but this disadvantage is more than offset by the advantage of having attention given to each machine. The best record made for harvesting is 400 acres of wheat in four days with the large tractor pulling four 8-ft. binders. As Mr. Sordelet said, "when making a record like that we do not recognize the eight-hour day, but get into the field early, stay late and hustle. That is the only way to do farm work anyhow," he continued; "when the time is right, put in long days; loaf in the winter time. On the basis of a year's time, our days do not average overly long, but in the busy seasons we are out in the fields early."

The experience with the motor cultivators used for the first time last year has been very satisfactory. The quality of the work was just as good as with the horse-drawn cultivators, and one man could cover more ground. Mr. Sordelet was especially pleased with the work done in the first cultivation. The rate of travel is slow and steady. No difficulties are experienced in crossing the corn, although the rate of work is greater when traveling with the rows. With the motor cultivator they average 10 acres per day the first time over, 12 to 15 acres per day when crossing, and 20 acres per day the third time over.

Here is the vision of a motorized farm that is gradually being realized. It has taken time, but relatively few mistakes have been made. The arrangement of the farm has been completely changed. The war seriously interfered with carefully laid plans, especially in relation to drainage. They have had to wait on the development of the motor cultivator. In addition to all this the income from the farm has had to finance the change from animal to mechanical motors.

Considering the size of the undertaking and the difficulties encountered, the progress to date has been satisfactory. It stands as a concrete example that power farming can be economically used in connection with a system of farming which builds up the fertility of the soil.—E. A. White in *Farm Implement News.*

EVAPORATION LOSSES FROM CRUDE OIL

THE results obtained from many tank experiments emphasize the fact that evaporation of oil depends on its temperature and the amount of disturbance to which it is subjected. In open tanks much more oil will evaporate on a cool windy day than on a hot still one. A so-called "gas-tight" metal roof is better than one made of timber because it is a better retainer of the gases that arise from the oil. The atmosphere above the oil in a tank is always saturated with oil vapors and absorbs more vapors only at the same rate as that at which they are escaping through the roof. Therefore, in a tank with a gas-tight roof, as soon as the space above the oil becomes saturated no more evaporation takes place.

When the sun heats the outside of an unprotected tank the oil and gas inside expand very rapidly. In fact, in many of the oil fields the temperature is sufficient to distill the higher fractions from the oil while it is in the tank. For maintaining a low temperature, the lagged or shedded tank gives good protection, as it is surrounded by still air that makes an excellent insulation. Other kinds of protected tanks in the order of their low temperatures and decreased rates of evaporation are (*a*) the water-sprinkled, white painted tank, (*b*) the water-sprinkled, black painted tank, (*c*) the glossy white painted tank, (*d*) the water-topped tank, (*e*) the black painted tank and (*f*) the oil-stained, loose-roofed tank. The rate of evaporation decreases with the decrease in temperature of the oil under ordinary conditions. The part of the oil that evaporates is gasoline, which is at the present time the most valuable part of the crude. Such data as have been collected show that the annual losses in large tankage range from 5 to 25 per cent.—A. R. Elliott, Bureau of Mines.

USE OF THE NAME OF THE SOCIETY

SEVERAL members have called attention to the fact that the letters "S. A. E." have been used in connection with so-called automotive engineering laboratories. It should be understood that the Society has no such laboratory and has not authorized the use of its name or initials in connection with any laboratory or other such commercial activity. Under its constitution the Society cannot approve any engineering or commercial enterprise, or consent to the use of its name or initials in any commercial work or business, except to indicate conformity with its standards or recommended practices. The right to use the emblem of the Society is granted only to members thereof and then only for Society purposes.

The approved abbreviations of the title of the various grades of membership are as follows:

For Members—M. S. A. E.
For Associates—A. S. A. E.
For Foreign Members—F. M. S. A. E.
For Service Members—S. M. S. A. E.
For Juniors—Jun. S. A. E.
For Departmental Members—Depart'l Mem. S. A. E.
For Affiliate Members—Affil. Mem. S. A. E.

Single-Disc Metal Wheels

By A. L. PUTNAM[1] CLEVELAND SECTION PAPER

ALTHOUGH disc wheels have not been produced in such great quantities as some of the other types, they have advanced far enough in practical application to demonstrate their possibilities and fundamental correctness, against handicaps that older types of wheel never had to overcome. The conception and development of the wooden-spoke wheel date far back into antiquity. This gives it an immense advantage when it comes to the practical application of any other type. The design of automobiles has naturally had a tendency to grow up around wooden-spoke wheels. Other types must be wonderful indeed to enable them to be applied commercially. Many vigorous criticisms are not really pertinent to them but to their application to a vehicle having incorporated in it certain features brought about by the fundamental idea of the use of wooden wheels.

Distinction should be made between the wheel itself, the single-taper dished disc and other features such as tire, rim and hub applications. Single-taper dished-disc wheels were developed in France and in this country at about the same time but, on account of the variation in European and American tire practice, the resultant wheels took different forms. As the use of dual rear tires in Europe was common, advantage was taken there of the ability to dish the disc outward from the rim to the hub, bolting the discs together near their periphery. A good working wheel was made, but at a considerable sacrifice of other features. Whether the disc is dished outward or inward has no bearing whatever on its resistance to side-strains, but a very marked effect upon the ability to support the load radially. The greater the distance from the center of the tire to the point where the wheel disc comes in to the hub flange, the greater are the leverage and the consequent fiber stresses at that point. In this country, because the use of dual rear tires did not have to be considered and the mounting of straight-side tires was prevalent, the dished disc took an entirely different form. It was dished in to the approximate center of the wheel, as this allowed the employment of a thin disc, permitted the use of only one hub flange for the brake drum and wheel and gave an opportunity for shortening the rear axle when desired. With due consideration for the merit of the straight-side tire as a tire, it puts a much greater burden on the rim-maker than the soft-bead clincher type. It produces unbalanced strains on the rim and thence on the wheel; the clincher type partly balances the strains. A straight-side rim must be reinforced radially more than a clincher, to prevent pinching or chafing of the tube against the bead of the tire. A single-disc wheel for use with straight-side tires must be equipped with a rim that will absolutely protect the disc from radial local strains, if the disc itself is to have long life. In the case of the wire wheel with its metal felloe, this factor is not so important. Many good records that wire wheels have made with clincher tires cannot be duplicated with straight-side tires, with the same spoke and hub construction.

It has always been easy to construct a metal wheel of ample strength under static test. But there was failure after a few years' running, local strains causing overfatigue and consequent cracking of the metal. In a properly designed single-taper disc the strains are diffused over the entire surface and the fatigue of metal is postponed to such late date that it need not concern us. Slight familiarity with efforts to construct double and triple-disc metal wheels, with reinforcements and attendant complications, shows the superiority in design and performance of the single disc. A single disc 3/16 in. thick at the center and 1/16 in. thick at the outer diameter will support a good-sized powerful touring car in a satisfactory manner.

The impression is firmly fixed in the minds of most automobile users that the wheels on their cars are resilient and that this has an important bearing on car operation. In an automobile 95 per cent of the shock absorption is effected by the pneumatic tires and springs, aided by looseness in the bearings, deflection of the axles and frame, the steering connections, etc. By springs is meant both the leaf springs connecting the frame to the axles and the cushion seat springs. Few realize how important the latter are until they go out in a supposedly easy-riding car in which solid stuffed-hair cushions have been placed. Nothing in any particular pneumatic-tire wheel construction has a marked effect on the riding qualities of the car. Different constructions of wheel certainly have different characteristics under certain classes of shock, but the wheel yield, being so small a percentage of the total yield, has a negligible effect on the riding of the car.

Given the data as to the service expected, the weight and the power of the car, the single-disc wheel will compare favorably with any other type as regards weight. It is self-cleaning. It negotiates deep soft roads of semi-frozen mud without packing up. It handles and steers in deep snow very much better than any other type.

[The discussion of this paper is printed on page 442.]

[1]M. S. A. E.—Research engineer, Detroit Pressed Steel Co., Detroit.

INDUSTRIAL ALCOHOL

NO development in the utilization of alcohol is more significant of its importance to industry than the enormous increase in the consumption of denatured spirits in the United States since the passage of the so-called "free alcohol law" of 1906. The consumption of denatured spirits grew from 1,780,000 gal. in 1907 to 10,404,000 gal. in 1914. Then came the war demand for denatured alcohol, for the production of munitions and poison gases, until the consumption of specially prepared denatured spirits reached over 55,000,000 gal. in 1917. In 1918 it dropped back to 50,163,000 gal. At present the capacity for the production of industrial alcohol in the United States is only 46 per cent of that which existed in 1918.—*Oil, Paint and Drug Reporter.*

WORLD DEBT

IN 1914 the combined national debt of the world was $28,500,000,000. By 1919 it had increased to almost $241,000,000,000. This total includes the debt of the United States and of Russia.—Bankers' Trust Co.

Wood Truck Wheels

By S. Vance Lovenstein[1]

Cleveland Section Paper *Illustrated with* Photographs

In the paper entitled Steel Truck Wheels, by P. W. Klinger,[2] some important matters are not given consideration. He does not credit wood wheels with the service they render daily in the transportation world, but belittles their enviable reputation, saying

> While recognizing that in the past the majority of trucks have been equipped with wooden wheels which, as a whole, gave good service, we believe the time is fast approaching when the result demanded in service will make imperative the substitution of steel wheels on medium and heavy-duty trucks, thus eliminating practically the last important truck unit made of wood.

The whole aim of the steel-wheel industry seems to be to produce a wheel that will give as good service as wood wheels have rendered for many years. This does not mean a wheel that will merely survive a laboratory test, but one that will give years of actual service filled with hundreds of thousands of economic miles. The danger of disintegration due to molecular vibration is not by any means confined to wheels alone. Some very important parts of the modern self-propelled vehicle that are unprotected by spring suspension, such as axles, axle housings, differential gears, propeller-shafts, universal-joints, wheel bearings and the component parts of these units, are subject to disintegration and excessive vibration transmitted to them is deleterious.

In an endeavor to produce steel wheels to replace wood wheels, the effects of vibration on metal wheels could not very well be overlooked. These effects, transmitted undiminished to the unsprung parts of the truck, seem to have been sadly neglected so far as preventives are concerned. Careful investigation shows no laboratory break-down test registering the metal fatigue in steel wheels caused by vibration. Wood wheels are not affected by vibration and so no such test is necessary for them. Why mention the unsprung parts? One can only wonder what was happening to them during the intervals mentioned in the following paragraphs. Under the heading What Is Required in Design, some interesting data are given on the result of vibration to the steel wheels themselves. The author says

> The design for steel wheels must be such that vibrations resulting from road shocks are not concentrated at any one point but distributed over or dissipated throughout the entire wheel structure; otherwise metal fatigue eventually results. Materials having a low elastic limit are not suitable for truck wheels any more than malleable or wrought iron is for vehicle springs, as a successful metal wheel must have a certain degree of resiliency.

We note that a successful metal wheel must have a certain degree of resiliency.

> Many of you have no doubt had experience with the early designs of built-up metal wheels and are well acquainted with the difficulties of loosened rivets and bolts, as well as with cracks developing in some types of cast disc and spoke wheels.

Here is the crux of the whole situation. Vibration loosened those bolts and rivets and developed those cracks. Why attempt to combat vibration with that material which is most susceptible to its damaging effects, namely, steel or any alloy with iron as its base? Its weaknesses are again emphasized when the author says

> All steel or iron castings are composed of crystals which are formed as the metal cools and run as consistently as the fibers in wood. Just as the weak spots in wood are where the branches run out, so the weak spots in castings are found where the right-angle joints occur.

Every one knows that only the straight-grain portion of wood is used in wood wheels.

> A hollow-spoke hollow-rim construction with a semi-flaring attachment to the rim is a partial recognition of this fundamental feature, but a full realization of it is attained only by the hollow-spoke wheel where the spokes join the rim in broad sweeping curves, giving an arch-like support to the rim

This advocate of steel wheels with broad flaring spokes says that this construction eliminates metal fatigue due to vibration. But what becomes of the vibration? Surely it is not absorbed in the wheel itself, which is made entirely of steel. It must therefore be transmitted to the wheel bearings and from them to other unsprung parts of the vehicle. Wood has wonderful resiliency, and therefore maximum vibration-absorbing qualities. The ingenuity used in wood-wheel spoke construction is devoted not to protecting the spoke but to absorbing all vibration within the wheel so that it will not be transmitted. This is in contrast to the cast-steel wheel, which must be so constructed that vibration will not prove fatal to it. This should be borne in mind when reading the continuation of the paragraph just quoted.

> at the same time avoiding objectionable crystalline formation and placing the metal so that the high elastic quality of steel is utilized somewhat in the form of a spring instead of as a dead strut.

In connection with the paragraph Strength of Wood and Metal Wheels Compared, the results of the tests shown are reproduced in the accompanying table. In this paragraph the author says

> It should be noted that the wood wheel was not loaded above 60,000 lb. as the speed of deformation indicated an approach to the yield point.

This statement is not entirely accurate. It so happened that when this test was made by the Bureau of Standards, the Quartermaster Department of the Army did not have a new wood wheel for the test and one was taken from a truck that had traveled many thousands of miles. This is verified by the official report of the director of the Bureau, which says

> This wheel had been used on a truck for some time and there were no identifying marks on it. It is thought, however, to have been a Schwarz wheel.

This wheel had to be used for both radial and side-thrust tests. The official figures show that with a radial load of 60,000 lb. a deformation of 0.1062 in. was

[1]M. S. A. E.—President, Schwarz Wheel Co., Philadelphia, and President, Automotive Wood Wheel Manufacturers' Association, Chicago.

[2]Printed in The Journal, August, 1919, p. 160.

STRENGTH TESTS OF METAL WHEELS

36 x 5-*in. Front Wheels*

Type	Weight, lb.	Maximum Radial Load Applied, lb.	Deformation at Maximum Load, in.	Permanent Set at Maximum Load, in.	Ultimate Side-Thrust Loading, lb.
Pressed Steel, Built-up	147	40,000	.....	.....	30,500
Malleable Iron	147	60,000	0.0677	0.0259	27,600
Cast Steel Disc	169	60,000	0.0359	0.0187	48,100
Cast Steel, Hollow Rim, Hollow Flaring Spoke	100	60,000	0.0645	0.0220	49,200
Wood	Front Wheels Not Tested				
36 x 10-*in Rear Wheels*					
Pressed Steel, Built-up	341	75,000	0.4153	0.3425	43,200
Malleable Iron	266	100,000	0.1928	0.1180	42,500
Cast Steel Disc	268	100,000	0.0881	0.0261	75,500
Cast Steel, Hollow Rim, Hollow Flaring Spoke	286	100,000	0.0513	0.0113	101,000
Wood	252	60,000	0.1062	0.0336	43,700

registered. That was not a permanent deformation, but the deformation at the time pressure was exerted. It was the resiliency of the wood that permitted this deformation, and the same resiliency returned the wheel

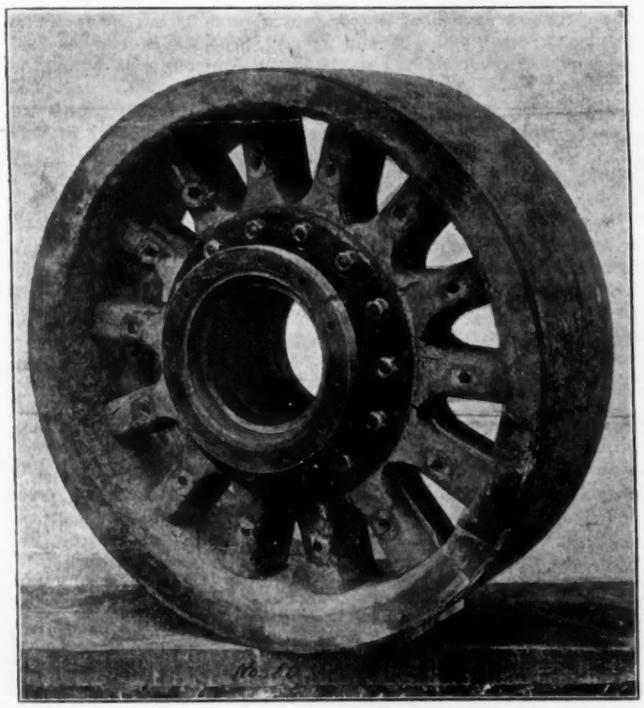


FIG. 1

to almost its original set as soon as pressure was released. Had this test been made under working conditions, the motion of the wheel coming in contact with the road over its entire circumference would soon have worked out all deformation, through the effect of the wood-wheel spoke construction. It was not due to "the speed of deformation indicating an approach to the yield point" that no more pressure was applied. A letter from the Bureau of Standards says

> The wheel was not loaded to destruction in the radial compression test as it was necessary to use the same wheel for the side-thrust or skid test

Fig. 1 is a photograph of the wood wheel after being subjected to both tests. Mud, grease and lack of paint show plainly its length of service before being used in these demonstrations.

In addition to the tests already mentioned, tests were made at the civil engineering laboratory of the University of Pennsylvania on Schwarz wooden truck wheels. A 2½-ton 36 x 4-in. dual rear wheel, with twelve 2½-in. spokes, with S. A. E. band applied, was subjected to a radial compression test of exactly 100,000 lb. The wheel was tested in compression by supporting it on a cast-iron block and stressing it radially by applying the load through a spindle passed through the hub of the wheel. The area of the block in contact with the circumference of the wheel was equal to a 6-in. arc on the full 8-in. face of the wheel. The load was applied in increments of 10,000 lb. At 70,000 lb. a slight cracking was heard, but no distress was visible. At 100,000-lb. pressure two spokes started to bend, and the sum total of the damage was that two spokes on each side of the load were drawn 3/16 in. away from the wood felloe; these resumed their former position within 1/32 in. after the load was released. The total deflection of the wheel under a 100,000-lb. pressure was 25/32 in. Fig. 2 shows that the wheel suffered no pronounced damage. In fact, it is safe to say that it could be used in service for many

FIG. 2

thousands of miles. This is still another proof of the strength, resiliency and efficiency of wood wheels.

Under the paragraph Metal Wheels in Service, Mr. Klinger says

> Probably the companies having the best opportunity to follow-up wheels in service are the London General Omnibus or the Fifth Avenue Coach Co., both of which use metal wheels exclusively

The latter part of that statement is not correct, for both companies use some wood wheels. It is admitted that these companies have the best opportunity "to follow-up wheels in service." One of them has recently expressed the intention to replace all metal wheels with wood. This intention has already been put into effect.

A large amount of publicity has been given to the unproved assertion that the world is rapidly approaching a wood famine. There is a wood shortage today, but it is a shortage of cut wood and it is due to labor shortage only. The reports of the Government Forestry Bureau show that in 1913 there was cut 38,387,009,000 ft. of lumber, and in 1918 only 29,262,020,000 ft. This is a large difference but it was due to a labor shortage. In the meantime nature continues to produce more wood. There is enough wood suitable for wood wheels to last for many generations and even beyond that time, when wheels will no longer be used for locomotion. Wood wheels have been used for a long time and will continue to be used on the world's best cars.

[The discussion of this paper is printed on page 442.]

SINCE THE ARMISTICE

THE signing of the armistice found the United States of America in what was probably the best financial condition of any country of the world at that time. There was over $3,000,000,000 in gold in the country and there was an outstanding circulation of $2,562,517,000 in Federal Reserve notes, $721,879,473 in National Bank notes and $346,681,016 in United States notes. National Bank deposits were $10,437,443,000. The reserve of the Federal Reserve Banks held against outstanding circulation and deposits was 49.9 per cent. The United States Treasury Department, which had been authorized by Congress to make loans to Allied nations up to $10,000,000,000, had made actual payments of $7,077,114,750. The United States Government had borrowed of its people $22,224,238,300 through Liberty Loans and had a floating indebtedness of $1,208,000,000.

While at the time of the armistice the United States Treasury could have consistently refused to make any further advances to the Allies from the funds authorized by Congress, with the exception of such amounts as had been allotted, nevertheless it continued to make payments to the Allied nations up to an amount in excess of $2,000,000,000. Loans to European countries have been made through American bankers since the armistice amounting to something over $500,000,000, and unknown millions which run into very large figures have been transferred by individuals for the purpose of investment in Europe. Further millions upon millions have been given outright by the American people to aid those in Europe in need of relief. In addition to these sums the United States War Department has taken the obligations of European governments for over $100,000,000 worth of supplies of various kinds needed by such governments for reconstruction purposes. The value to Europe of these particular transactions is shown in the fact that the War Department delivered locomotives and rails, a tremendous amount of machine tools, various textiles and many foods from the supplies which it had accumulated for the purposes of war.

The American Relief Association began supplying food soon after the armistice to the central and eastern countries of Europe, except Russia, in quantities hardly believable, and accepted foreign government obligations in part payment therefor amounting to another $100,000,000. The American Red Cross has never stopped its stream of supplies from America to Europe to take care of relief work pertinent to its organization, and the value of such shipments since the armistice is $60,000,000. Since Jan. 1, 1920, the United States has arranged for the delivery of 5,000,000 bbl. plus 35,000 tons of flour against foreign government obligations of $60,375,000. Further advances of supplies by the United States War Department have been made to the amount of $50,000,000. The United States Shipping Board has accepted obligations for shipping furnished to carry War Department and food supplies to a total of $3,580,000.

Without including any of these items where we have not the exact figures, even though it is known that the totals run into millions of dollars, a statement of advances made by the United States to European countries since the armistice totals nearly $5,000,000,000, which is four times the amount of the public debt of the United States before the war and somewhat in excess of the prewar debt of Great Britain and Germany combined. If the United States Government had made no further advances to European countries after the armistice the Victory Liberty Loan of 1919, to which the people of the United States subscribed $5,249,908,300, need not have been placed. In other words, after the pressure of war was over the people of the United States paid into their Government over $5,000,000,000, 90 per cent of which was required because of money advanced for the benefit of Europe.

A large part of the proceeds of such credits as have been extended has been wasted, as those receiving them have not been able to use them economically and later generations will be obliged to pay the loans with a far greater quantity of production than present generations have received, and all out of proportion to the ordinary price fluctuations which normally take place and that one must expect to meet when borrowing today and paying in the future.

All who supplied the wants of others in every nation of the world during the war period of necessity made money profits almost without the use of any sort of judgment in their operations, as they were buying supplies for future sale on a rising market. There are, of course, those who have abused the opportunities for profit offered, but they can be found in every country. Before the United States entered the war its people, because of high prices paid for prompt delivery, made unusual profits when supplying Allied wants. Since the United States entered the war our Government has had to borrow over $25,000,000,000 from its people, who promptly responded to every call made upon them.

The United States is buying more from South America and Far East than it is selling. It is selling more to Europe than it is buying, largely because Europe cannot produce an equivalent.

In America we will never forget the steadfast power and wonderful force of the British nation; we will never forget that little Belgium, a nation of tremendous industry, deliberately sacrificed itself and lived under the arm of the invader for the benefit of us all. We can never forget how Italy at a most crucial time threw her armies into the maelstrom of war for the great general good. Who can forget glorious France, the country which for four long, bloody years furnished the battleground over which the greatest armies that the world has ever seen, with the greatest power of destruction known to man, tramped back and forth with the tide of war? It is beyond the power of the human heart to forget France.

In working out the world's problems together honest differences of opinion we will all have, but because of them and through them our intelligence will grow and if we maintain proper confidence in each other the progress of the world will be advanced by mighty strides.—Fred I. Kent.

Wire Wheels

By C. S. WALKER[1]

CLEVELAND SECTION PAPER *Illustrated with* DRAWINGS

WIRE wheels are by no means new, but have been known and used for more than 500 years. The early wheels merely rolled, carried weight and resisted side strains; later they were called upon to transmit braking forces and still later the driving force.

Prior to the coming of the automobile, wire wheels were not called upon to support much weight. The usual type was that used in bicycles; comprising two sets of spokes extending from two circles, one at each end of the hub, to a single circle at the middle of the rim. When automobiles were first made, the wire wheels then being used for bicycles were of course employed. They continued in use until the demand for larger wheels and for heavier automobiles presented obstacles unsurmountable by the bicycle-type wheel. Wire wheels of the bicycle type should not be more than 28 or 30 in. in diameter. Even if heavier spokes are used, such wheels are not capable of supporting heavy automobiles. Furthermore, they could not be offset to permit their substitution for wood wheels of the artillery type. From 1904 to 1910 practically no automobiles in the United States were equipped with wire wheels.

FIG. 1

FIG. 2

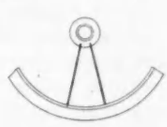


FIG. 3

Contrary to general opinion, the same condition existed in England. However, Rudge-Whitworth, Ltd., the bicycle manufacturer, did much experimenting there. In 1905 he brought out the double-spoked offset wheel which was used on a Napier car in the Gordon Bennett elimination trials. Wood wheels were nevertheless used almost exclusively until 1909. Rudge-Whitworth then brought out his triple-spoke wheel, which met all those requirements which the bicycle-type wheel failed to meet. It proved to be a great success and caused a sudden shift back to wire wheels; in fact, nearly half the cars manufactured in Great Britain in 1911 were fitted with them. A few of these wire-wheel equipped cars were imported into this country and, while the wheels appeared frail, they soon proved to be superior in strength to wood wheels. In spite of the feeling against wire wheels, the triple-spoke wheels have grown in popularity since 1912, when they were first manufactured in this country. There are millions of them in use.

TYPES OF WHEELS

What a triple-spoke wheel is and why it is superior to any other type will best appear from a consideration of the stresses and strains that must be resisted by a wire wheel and the manner in which they are met. If the wheel had an absolutely rigid rim, the hub could be supported by a single spoke and the tension on it would equal the load. If we add the bottom spoke and both spokes had a certain initial tension, the load would be supported by an increase in the tension of the top spoke amounting to half the load and equivalent decrease in tension of the bottom spoke. The horizontal spokes have no function to support the hub, in a wheel with a rigid rim, unless a considerable load is added.

Let us now consider a wheel having a flexible rim of the type ordinarily used in automobiles. The load will tend to flatten the top of the rim and bulge out the sides. The horizontal spokes prevent this and, in fact, all but a few of the top and bottom spokes of the wire wheel cooperate to keep the rim true and thus help to support the load. Experiments have shown that only about one-sixth of the spokes, that is those below the load, have no load-supporting or rim-truing function. To transmit the driving and braking forces, the spokes are laced tangentially to a circle which may or may not be the same as the circle on the hub to which the spokes are fastened. The custom is for alternate spokes to extend from the hub in one direction and for the others to extend in the opposite direction, so that the wheel is subjected to the same torque in either driving or braking.

A single row of spokes will resist vertical loads and driving and braking torques but not side strains. In the arrangement to perform this additional function lies the difference between the different types of wire wheel. The first is the bicycle type, in which two cones of spokes extend from separate circles on the hub to a single circle on the rim. So long as bicycle-size rims were used this type was very satisfactory, but when wider rims were introduced something different was needed. Several methods were used, the most common being to provide two spoke circles at the rim and lace the spokes as in Fig. 1, or to cross them as in Fig. 2. The first method was better because the spokes prevented the rocking of the rim. The second method would not hold the rim in place. The wheels were symmetrical, the center line of the rim coinciding with the center line of the hub. They would not of course give the same track if substituted for wood wheels. Attempts to meet this objection were made by offsetting the rim relatively to the hub, and shortening the length of the inner set of spokes. The double-spoke type shown in Fig. 1 could not give sufficient offset, because its limit to offsetting is reached before the inner spokes are at right angle to the axis of the wheel. The crossed-spoke type gives sufficient offset but has inherent weakness as stated.

The triple-spoke type (See Fig. 4) is not merely an adaptation of former types but an entirely new wheel having three sets of tensioned spokes, at different inclinations, joining the hub to the rim to form an unsymmetrical or offset wheel. Set *a* ex-

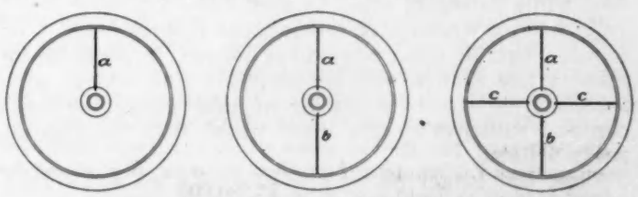


FIG. 4

[1]Patent Counsel, Wire Wheel Corporation of America, Buffalo.

tends from the outer end of the hub to the rim at a great inclination; set *b* extends from the inner end of the hub at a considerable inclination, in the opposite direction to set *a*, to the outer half of the rim, to pull the rim inward and to counterbalance the pull of the set *a;* and set *c* extends from the inner end of the hub to the inner half of the rim, to make the wheel rigid. Sets *b* and *c* do the driving and the braking, while set *a* resists lateral strains from the outside. A tendency of the rim to tilt in any direction is resisted by certain spokes acting longitudinally, in the direction of their greatest strength.

Disadvantages and Advantages of Wire Wheels

The two great objections to wire wheels are the difficulty of washing them and the breakage of spokes. The first is, I believe, largely psychological and can be attributed to the difference in size of wood and wire spokes. If a brush such as is furnished by all wire-wheel makers is used instead of a sponge or chamois, this difficulty will largely disappear; further, wire wheels do not need washing as often as wood wheels, because they do not hold dirt and mud so easily.

Spoke breakage has been given much study. I believe we have solved this question in our new spoke. Tests conducted at our factory show that a wheel laced with the new spokes will withstand from 300,000 to 400,000 starting and stopping oscillations before a spoke breaks. Assuming that a car is stopped and started an average of five times per mile, the wheels should run from 60,000 to 80,000 miles without a break. We did not discontinue our tests until six spokes were broken at from 800,000 to 1,500,000 oscillations, which, following the same assumption, means from 160,000 to 500,000 miles. Even with six spokes gone the wheel does not collapse. Spoke breakage is in some cases due to non-circularity of the rim, undue strain being put on certain spokes in properly truing up the wheels.

Wire wheels mean safety first, last and all the time. Axles may bend and tires may come off, but wire wheels cannot collapse. They come through skidding accidents or collisions practically undamaged. Strength is the reason for the safety of wire wheels. Steel is stronger than wood. Steel spokes are stronger than wood spokes. Each wire spoke in a wire wheel is strong enough to stand a strain of 3700 lb. The lateral strength of a wire wheel is greater than that of a wood wheel. The triple-spoke lacing provides for taking strains from any direction. Strength that has proved itself against the racking strains of racing automobiles is the strength that should be in every car. Racing-car drivers whose lives depend upon the wheels under them use wire wheels. Airplanes are equipped with wire wheels, not only because they are lighter but because they are strong enough to withstand landing strains. The strength of wire wheels was shown in a railroad accident that occurred near Buffalo. A car equipped with wire wheels was struck by the Chicago limited running at great speed. Although the car was carried half a mile, one wire wheel was completely wrecked; one was not damaged; the other two, while damaged, could be used.

With wire wheels tire replacement requires only 4 or 5 min., but 20 min., sometimes longer, is required to make a tire change with demountable rims. With wire wheels it is simply a matter of unscrewing the hub-cap and substituting the spare wheel, with the tire already inflated.

Tires last longer on wire wheels than when mounted on the heavier, heat-retaining wood wheels. While I have no records of actual tests available this seems obviously true. The metal rims and spokes of a wire wheel carry off heat generated in the tire. With heavy-rimmed wood wheels and demountable-rim equipment the tires receive greater punishment.

The light-rimmed wire wheel is the antithesis of the flywheel. Its greater mass being at the hub, and not at the rim, it is easier to start or stop than the demountable-rim equipped wood wheel.

It is well known that the unsprung weight in a car causes greater fuel consumption and tire wear than the same weight above the springs. A saving in unsprung weight means reduction in the actual load and less power required.

Resilient, light-rimmed wire wheels on the steering-knuckles require less strain and tend toward greater certainty in the handling. Wire wheels also offer less resistance to the steering-wheel, as they are resilient enough to climb out of ruts and over bumps more easily than the heavy-going wheels.

Longer car life and easier riding are assured by wire wheels; on rough roads they absorb shocks that other wheels transmit to the car. As the wire wheel is a "suspension" wheel, the car weight is hung or "cradled" from scores of resilient, flexible spokes. This reduces running vibration, protecting the vital mechanism and reducing repair bills. In the wire wheel the pull is always on three-quarters of the spokes. In the compression-spoked wheel the weight is on but one or two of the rigid spokes at a time; this applies with equal force to the compression disc wheel.

The Discussion

C. C. Carlton:—Wood wheels are built to the blueprint specifications of automobile engineers who know more about them than the manufacturers themselves. Few wood-wheel designers are called in and asked their opinion. About three weeks before a new model of car is put out, we are presented with a set of blueprints. We start the wheel production. That is wrong; that is what we are trying to combat. Many cars in America are using wood wheels that are not what they should be. The day will come when the designers of automobiles will call upon the wheel designer and listen to him as they listen to other designers. That will give an opportunity for building proper wood wheels. Out of 27 manufacturers, we had blueprints from only six. That is the position in which the wood-wheel manufacturers have been placed. They have built a wheel in some cases to their own design and in other cases to the blue-print design of some other engineer. The Class B truck went out with wood wheels that were not guaranteed. We have a record of 23,000 wheels which were not guaranteed, of which only three have been replaced.

Regarding flexibility, why are airplane propellers made of wood? Why are hammer handles, baseball bats, golf sticks, violins and victrola boxes made of nothing but wood? Wood has a shock-absorbing quality. This is a feature of wood wheels not often discussed. Wood floors in factories are there for the same reason that wood wheels are under trucks and that wood ties are under railroad tracks; the timbers placed under the drop-forge hammer serve the same purpose that the wood wheel serves under a car. Wood has been and is the greatest preventive of crystallization in steel.

Much has been said about unsprung weight. In making a comparison of weights of wheels there is nearly always a change of felloe bands, hub equipment or something else. Wood wheels cost more than they did and

the timber is hard to get; the cost figures show that labor has increased 30 per cent, material 20 per cent and wheels 100 per cent. A real attempt is being made to build better wheels. If an engineer says that he is not securing the proper quality of timber, he is wrong. Nature is growing the same type of hickory and there is an ample supply of it. Forestry statistics show that more timber is standing than could be consumed if we should run 100 per cent for the next 50 years. The shortage was acute because the Government bought immense quantities of timber, but we were able to buy it back and put it into the wheels we are making.

When we write a guarantee we do not limit it to a specified number of years. We have been bold enough to guarantee wood wheels for the life of the truck or the automobile on which they are placed and for the service for which they are intended; they were never intended to be hit by a locomotive. The automobile builder demands three things, other things being equal; a guaranteed service, good appearance and a low price. The wood wheel has fulfilled its mission in the past. I need only ask what owners have done to the wood wheels on their cars to help them give the service they should, and how many times have they had their wood wheels repaired? Wood wheels will not squeak if the timber is properly seasoned.

W. H. BROWN:—Is it true that it is much more dangerous to run a wire wheel with a flat tire than a wood wheel?

C. S. WALKER:—I do not know.

J. M. CRAWFORD:—The engineers of today are not going to build their cars around wheels. It is certain that the light car has come to stay. Wheels must be made to suit the car. Light cars will perform as well as the heavier cars if they are equipped with the right type of wheel. My experience has been that there is a certain ratio of unsprung to sprung weight that must be maintained for easy-riding qualities, and the wheel for the lighter car must be lighter than the wheel for the heavy car. I have not noticed any particular difference between the action of wire and wood wheels, but I do notice a difference in disc steel wheels. I am in favor of the wire and the wood wheels because of the great weight of the disc steel wheel.

A. L. PUTNAM:—I made the statement that there is no difference in the weight of the disc steel wheel, the wood wheel and the wire wheel, when opportunity is given to install the disc wheel as it should be installed on a given car. The disadvantage of the disc steel wheel has been its novelty. We had so many types and sizes of rim that it took some time to get the right wheels for any particular car.

UNSPRUNG WEIGHT RATIO

F. JEHLE:—In regard to unsprung weights and the designing of the proper wheel for a given car, has anyone any figures on the proper ratio of unsprung to sprung weight? In designing a car weighing say 3000 lb., how heavy should the wheel be?

MR. PUTNAM:—The wheel should be made as light as possible to give the service required. On a 3000-lb. car the wheel and rim should weigh 36 or 37 lb.

MR. CARLTON:—We had blueprints of a 32 x 4-in. wheel for a 2500-lb. car. The hub construction called for an 8½-in. flange diameter. We would have been compelled to use a spoke with a large head, to make the flange that large. We convinced the car manufacturer that a 7¼-in. flange is all that is needed to hold the wheel properly. By doing this we were able to use a spoke two sizes smaller in the head. That is the factor of importance. If we must start with a large head and cut the barrel down, we have a serious proposition. The Class B truck has a flange diameter of 15½ in. Fourteen spokes should be used to make up the 15 in. of flange. We had to use a billet large enough for a 5-in. spoke; so we had to take a split billet and save the head to get the flange diameter. That is being done in many cases. We are asking the manufacturers to change their wheel designs so that the amount of wood necessary to make a given wheel can be reduced.

H. G. WELFARE:—Regarding resiliency, does it act perpendicularly with the rim, or laterally with the hub?

MR. PUTNAM:—I make no claims of resiliency for the disc steel wheel. In the initial design of the wheel I had the best wood wheel I knew of made to order. I then tested it under all conditions and tried to duplicate it. The wheel gives under skidding strains and recovers. That the wood wheel is resilient radially on a pneumatic tire, I deny. It has a certain amount of give going around a corner. The steel wheel has the same property. The wire wheel when new and properly laced has no give whatever.

MR. WALKER:—I seem to be the only one who claims resiliency. I do not see why there is no resiliency in the wire wheel. The hub being suspended from the rim, it seems that there must be a certain amount of give to it; all the spokes are at an angle.

E. W. WEAVER:—I have noticed that on a slippery road surface everything about a car seems quieter. This I ascribe to the slip of the tire on the road surface, easing up on the shock all through the driving mechanism. If it were practicable to produce wheels with elasticity enough to give this effect all of the time, I would be very keen to have them; but I have not seen any such wheel. As to the wire wheel, is it resilient under normal load or abnormal conditions?

MR. WALKER:—The wire wheel is resilient under any condition, but this is more evident under heavy than light load.

O. A. PARKER:—Considering wheels abstractly, strength is the first requisite. The strength should be great enough for the service and the life should be long enough to outlast the car, for the wheel is an essential part of the car.

The second consideration in wheel construction is weight. I believe that none of the wheels has resiliency. Almost any structure will give to a certain extent and then recover, and that is the technical definition of resiliency; but I believe that there is no useful resiliency under normal conditions. The wood wheel has a capacity for absorbing sound vibrations. I understand that the action of the pneumatic tire will take up about ¾ in. of road unevenness with sufficient cushioning effect that it will not be felt. I think that the weight of the wheel has more effect on the riding qualities than anything else. The Franklin engineers have given much thought to this subject. They use a high-grade light wooden wheel with fixed rim and will not permit demountable rims on their cars. The putting on of heavier wheels causes a noticeable effect in the riding qualities of the car. The shocks transmitted come through the wheels; one kind comes from first impact and one from rebound. The rebound is proportionate to the weight of the wheel. The ideal condition would be to have no unsprung weight, which would require springs, axles and wheels of no weight. Light weight and, particularly, a light periphery are desirable in a wheel.

Means for making tire changes is third in importance. Most of the time is used in jacking up the car, and in getting tool and tire equipment out and putting it away, so that the actual time required for changing a tire is of less importance than is usually figured. A fourth consideration is appearance. The fifth is a method of cleaning without unnecessary care and trouble. The desirable thing in a wheel is a strong rigid light structure.

G. L. LAVERY:—When a wood wheel is resilient it is on its way to destruction; the nearer to destruction, the more resilient it is.

MR. CARLTON:—I stated that we never made any claims for resiliency; I do not mean that we are not claiming any cushioning effect for wood wheels. One can see very plainly the cushioning effect of the wood. When we began to build 40 by 8-in. wheels with short spokes, we had much difficulty. We found that the spokes were too short by 3¼ in. and that there was no flexibility in the wood. In the case of all other types there was a flexibility and give which permitted the wheel to assemble and seat itself. I know that there is a cushioning effect.

MR. PARKER:—I would not deny the cushioning effect of wood. A hammer handle is resilient because it has been narrowed down. Regarding the cushioning effect of a wheel when compressed, I have made a few investigations concerning the amount of pressure exerted by a wheel against a rim. The tension of the rim against a wheel is so many times greater than the load-carrying capacity of the wheel that it permits no real resiliency. When I said there was no resiliency in the structure, I meant no appreciable resiliency; that, with pneumatic tires and springs absorbing so much shock, there is no appreciable resiliency in a wheel.

MR. PUTNAM:—In connection with acceleration and effects due to the weight of the rim and different classes of wheel, the best way to test them is not on an automobile but on some machine with accurate methods of measurement.

W. C. KEYS:—The effects of heavy wheels are noticeable when the brakes are applied on a car with large peripheral weights. It is necessary to allow a greater distance to stop and it is difficult to slide the wheels, owing to the flywheel effect of peripheral weight. On the question of resiliency, I agree with Mr. Parker that there is no noticeable effect on riding qualities due to resiliency in the wheel.

A. M. DUDLEY:—Mr. Carlton mentioned railroad wooden cross-ties. One well-known road carrying iron ore has the greater portion of its rails on steel cross-ties, rolled in the section of an I-beam. These rails are the heaviest in use and the total tonnage per annum is said to be the largest of any road in the world. In spite of this heavy construction, derailments due to the lateral shock of the wheel flange on the rail are very frequent and I understand that there is a possibility of a return to the wooden cross-tie construction. On first analysis it would appear that, due to the greater inertia of the wooden tie and the much greater surface offered for friction on the ballast, the resilience of the wood construction would be less than with steel; but it does not seem to work out that way. To be sure, railroad-bed construction is an entirely different problem from the design of motor-vehicle wheels and the results with one do not necessarily follow with the other; but it is interesting to note the railroad problem in passing.

MR. PUTNAM:—Although they are not used in this country, there are metal cross-ties which are successful in all respects and have all the virtues of holding the rails. This particular kind of tie is used very successfully in Switzerland.

JOHN MCGEORGE:—Metal ties laid in concrete are used on a large percentage of the tracks of our street railways in the larger cities.

OVERSIZE TIRES

A MEMBER:—The outstanding impression that I get is that peripheral weight is something to be avoided to obtain easy riding qualities. On the other hand, the tire manufacturers advocate the use of oversize tires which increase the peripheral weight. How is it that the wheel and the tire manufacturers are working in opposite directions?

MR. PARKER:—Tires are one of the expensive necessities of a car. Without discounting any of the cars that are being sold, we all know of cars on which the tires are too small. To meet this situation the tire makers have made oversize tires. Oversize tires as equipment on new cars have been strongly opposed by tire and wheel men. The abuse of certain oversizes, such as 33 x 4 in. on 32 x 3½-in. rims, has led to such equipment as the 33 x 4-in. rim with a wider base. A 35 x 4½-in. tire is not as large in cubic capacity as a 34 x 4½-in. tire; in other words, a 34 x 4½-in. tire with its wider base, has a greater carrying capacity.

With regard to the peripheral weight of a large tire, I have never made tests, but there seems to be a difference between dead and live weight on a wheel. Solid metal seems to have a different effect than a thing like the tire itself; therefore, an investigation should show that a heavier tire does not have the same effect as the same amount of weight in the fixed part of the wheel near the periphery.

STANDARDIZATION OF HUBS

A MEMBER:—In connection with flange diameter, what has been done on the standardization of hubs?

MR. CARLTON:—Not much progress has been made. A joint committee representing the steel and the wood-wheel manufacturers has been attempting to work with the axle manufacturers to arrive at a standardization. The subject is to be assigned to a new wheel and hub division created by the Society.

A MEMBER:—What is the purpose of the standardizing efforts? Just what do you wish to accomplish?

MR. CARLTON:—We would like to eliminate some of the sizes of flange diameter. We have diameters of 7¼ and 7⅝ in. and others running by eighths, sixteenths and thirty-seconds up to 9½ in. Many of the axle manufacturers admit that there is no excuse for the large number of diameters. One manufacturer said he used a flange diameter of 7⅝ in. so that it would be different. I believe that there have been no valid reasons for some of the flange diameters.

MR. PUTNAM:—There are many types of axle which must have a very large flange diameter, regardless of the kind of car. On some of the light low-priced touring cars there is a bore of approximately 5 in. to start with, which means a 9 or 10-in. flange. Other heavier and larger cars have a very much saner type of axle on which the flange diameter can be made smaller. The bore and the flange diameter can be kept to a consistent standard. So long as there are three types of axle in use, one type will have a large flange and bore diameter regardless of the kind of car it goes on. There are some

high-priced cars whose hubs and flanges are relatively very inexpensive.

MR. PARKER:—Any proper design of wheel should be weak enough to fail before the axle fails. The wheel should be capable of absorbing shock, and be required to absorb it, rather than the axle, as it is easier to replace a wheel than an axle. A wood wheel collapses at once after it has passed its elastic limit. A metal wheel will continue to absorb shock until it has finally been bent over flat.

PUBLICATIONS AVAILABLE FOR PURCHASE

THERE are undoubtedly many members of the Society who will welcome an opportunity to supplement their technical libraries by purchasing copies of some of the older volumes of the TRANSACTIONS that are available at this time. This is true particularly of the more recent members who have received only the later volumes.

It seems hardly necessary to emphasize the value of the books. By far the greater percentage of the papers included in them are of permanent value. Many contain data which are not obtainable elsewhere. There are papers covering comprehensive heat-balance tests, engine balance, thermodynamics, chassis suspension, ignition theory and basic mathematical treatment of automotive engineering problems. Very little of this information is recorded in the few textbooks published which cover the several branches of automotive engineering. It has been the experience of the S. A. E. office staff, when assisting members in their study of various subjects, that the information sought can generally be found only in the TRANSACTIONS.

Copies of the TRANSACTIONS for the years 1917 and 1918 can be ordered now from the Society offices in New York City at a special price of $4 per copy to members and $7.50 to non-members. The stock of the TRANSACTIONS for periods previous to those listed above is more limited and necessitates maintaining the standard price of $5 per book to members and $10 to non-members.

The following papers are available in separate pamphlet form:

Aircraft Radiators—Archibald Black
Airplane and Seaplane Engineering—Com. H. C. Richardson, U. S. N.
Analysis of Fundamental Factors Affecting Tractor Design—Oliver B. Zimmerman
Application of Liberty Engine Materials to the Automotive Industry—Harold F. Wood
Automobile Lubrication—C. W. Stratford
Automotive Ordnance Apparatus—Lieut.-Col. William G. Wall, U. S. A.
Balance of Automobile Motors—Ernest R. Fried
Cantilever Springs—John G. Utz
Composite Fuels—Joseph E. Pogue
Data Pertaining to the Internal Combustion-Engine Fuel Problem
Dilution of Engine Lubricants by Fuel—Gustave A. Kramer
Dynamic Balancing of Rotating Parts—F. Hymans
Electric Lighting and Starting—Joseph Bijur
Electrical Heat Treatment of Steel—H. P. MacDonald
Fuel Economy of Automotive Engines—Dr. H. C. Dickinson
Heat-Balance Tests of Automobile Engines—Prof. Walter T. Fishleigh and W. E. Lay
High-Speed Engines—A. P. Brush
Liberty Aircraft Engine—J. G. Vincent
Measurement of Horsepower—Prof. W. Morgan and E. B. Wood
Measurement of Vehicle Vibrations—Benjamin Liebowitz
Mixture Requirements of Automobile Engines—O. C. Berry
On the Dynamics of Vehicle Suspensions—Benjamin Liebowitz
Relation of Motor Truck Ability to the Trend of Design—Lewis P. Kalb
Remarks on Dynamics of the Automobile—N. W. Akimoff
Size and Inflation of Pneumatic Tires—P. W. Litchfield
Tendencies in Engine Design—L. H. Pomeroy
Tractor Engine Test—C. A. Norman and B. Stockfleth
Ultimate Type of Tractor Engine—H. L. Horning
Universal Joint Efficiency—C. W. Spicer
Velocity of Flame Propagation in Engine Cylinders—R. K. Honoman and Donald McKenzie
Wire Wheels vs. Wood Wheels—George W. Houk
Working Processes of Future Internal-Combustion Engines—C. A. Norman

These papers are available at a reduced price of 20 cents each to members and 40 cents each to non-members. All orders should be accompanied by a remittance covering the cost of the TRANSACTIONS or papers only, as the carriage costs are defrayed by the Society.

FARM MACHINERY

MOST farmers will tell you they have all the machinery they need, and many of them will say they have too much. The ordinary implement dealer will tell you very few have a well-selected, well-balanced equipment. Most county agents will say the same thing. From what investigations I have made I should say the dealers and county agents are correct. When I visited Tompkins County, New York, I asked the county agent, V. B. Blatchley, what he could tell me of farmers' equipment and he gave it as his opinion that not more than fifty farmers out of 2000 in the county had the machinery they needed to do all their work efficiently.

Mr. Blatchley drove out with me to visit the Nelson F. Hopper farm near Ithaca, which, he said, was the best equipped farm in the county. Mr. Hopper owns 320 acres of land, does some general farming, has a well-kept, productive apple orchard and a herd of pure-bred Holsteins. His herd of dairy cows numbers about thirty milkers and the entire product is sold to an ice-cream factory. Mr. Hopper showed me his entire equipment. "It inventories," he told me, "a little more than $10,000, but would cost more than $15,000 at present prices."

Here is a list of his principal implements: A tractor, hay loader, mower, side-delivery rake, corn harvester, ensilage cutter, corn husker, potato planter, potato sprayer, potato digger, concrete mixer, wagons, manure spreader, disk harrows, peg-tooth harrows, engine gang plow, sulky plow, walking plows, two-row corn planter, two-row corn cultivator, other cultivators, grain seeder, harvester, hay fork, milking machine, feed grinder, electric lights and power pump in barn, stanchions and drinking cups, litter carrier, feed grinder, silo with 300 tons capacity, a land roller, orchard sprayer and ladders. Rather an imposing array of machinery, and yet nothing superfluous.

In these days when every farmer is obliged to struggle with his labor problem, and the future appears to hold scant hope of a return to old conditions, I cannot help but feel that the wise farmer will seek to change his methods, adopt the most efficient machinery and cast old prejudices aside. He will be patient in training what help he is able to command, realizing that when a man is placed in charge of a new machine for the first time he is obliged to learn a new trade.—P. S. Rose in *Country Gentleman.*

Discussion of Papers at the Summer Meeting

THE discussion of the papers presented at the recent Summer Meeting of the Society included written contributions submitted by members who were unable to be present and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, follow the discussions. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, in case it is desired to refer to the complete text and illustrations. An exception is noted concerning the paper on The Fuel Problem from the Refiner's Viewpoint, by R. L. Welch, which, together with the discussion, was printed in the September issue.

THE FUEL REPORT

THIS report deals with the application of exhaust heat to secure better utilization of present fuels in present engines. It is intended as a guide in burning the more or less volatile fuels known as gasoline and every effort was made to gather authoritative information as to the methods of doing this more efficiently. The method suggested in this report is one of several means whereby better vaporization can be accomplished. It was chosen because of its simplicity and ease of operation.

The report applies particularly to the preparation of mixtures from fuels of a wide range of volatility such as must be considered by the designer of engines and carbureters today. Up to the time that fuels of lower end-points than 302 deg. fahr. became uncommon, vaporization was not a difficult problem.

Modern carbureters are considered as being sufficiently accurate metering devices. With the heavier fuels commonly available, the heat accidentally available in carbureters, manifolds or from the combustion-chamber walls is inadequate for vaporization of the fuel under all conditions.

No general formula for the solution of a problem with so many variables, such as this, can supersede the judgment of an engineer. However, if engineers will work out the intake designs and apply the principles of design laid down in this report and temper each decision with judgment, marked improvement will result in the operation and service of any motor car or truck.

The report, therefore, centers on the preparation of proper combustible mixtures from the less volatile gasolines and involves consideration of questions of vaporization and distribution. [Report printed in full in the July, 1920, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN H. M. CRANE:—It seems to be a regular procedure now to have a fuel session at each one of our meetings and I think it will be so for several meetings to come. We know that fuel is an important subject, but our interest in it has been too personal, possibly limited by our activities in special lines, we not taking the broad point of view of the general question for the good of all.

We are credibly informed by those who ought to know that there is a definitely limited supply of the fuel that has made the automotive industry what it is today, the fuel which has made the simplest prime-mover in the world a practical possibility. There is no question that today, with the rather usual American habit, we are throwing this fuel broadcast with very little thought of the fact that tomorrow there may be none. We cannot go on in this way without facing the possibility that this industry, which has grown to be one of the largest in this country, will stop for lack of motive power. The most hopeful sign at present is the beginning of a cooperation between the makers of the apparatus in which the fuel is to be used and the men who supply the fuel. I wish I could say that there is some cooperation on the part of the individuals of the great public which uses the fuel. I have seen no such cooperation as yet. In the past, the automotive industry has been engaged in turning out the largest production possible. To do this it has had to meet a market, to sell at a comparatively low price and, in many cases, to let speed take precedence over efficiency. The industry is so strong now that it is time the precedent should be somewhat altered, and it must be altered if we wish to conserve the industry.

On the other hand, the producers and distributors of fuel have followed an exactly similar course. The fuel has flowed out or has been pumped from the ground at relatively small expense, and the owner of an oil well or refinery has sold what came out of the ground at the largest price he could obtain. As in every business, the largest turnover on the capital invested returned the largest profit, and I suppose that we cannot blame the refiners or the oil producers for the attitude they have taken. But they are now facing the possible end of this business. I believe that we can and should show them that it is to their advantage to more carefully consider their methods, to use more efficient means of refining and to see that no particle of the oil that flows out of the ground so easily is wasted in the refining and manufacturing processes.

There is no question that in the haste to get out the largest quantity of so-called gasoline or automotive fuel, a considerable quantity of lubricating oil is seriously injured. We need the lubricating oil just as much as we need the gasoline, and the two should be equally conserved. In other words, I think that the automotive industry must more carefully consider its output and the methods of fuel use. The fuel industry should consider very much more carefully whether their present methods of refining and distribution are the best available. I think it is an open question whether we would not be justified in demanding two grades of fuel. I have been told that such a condition held in California with very satisfactory results to users, one fuel being of a rather light grade, the other of a considerably heavier grade. Those who wished to obtain good road performance, good hill-climbing and good getaway, could buy the lighter fuel; those who wished to secure economy and low cost of operation, could buy the heavier fuel. I think there

is no justification for using the same type of fuel in all our different varieties of automotive apparatus.

In the case of the airplane, we have specialized with satisfactory results on a rather high-grade fuel. In the farm lighting-plant, kerosene is used to a large extent with entire satisfaction. It appears that further work along this line is well worthy of consideration. The whole question, if it is to reach a satisfactory conclusion, must be a matter of education for everyone; for those engaged in the automotive and fuel industries and, above all, the members of the great using public who today, in a perfectly thoughtless manner, are getting only about one-half the efficiency from the fuel they buy that they should get. If we cooperate with the fuel manufacturers and present a strong and united effort in propaganda to the user, we can hope to improve greatly the present conditions.

H. L. HORNING:—I take this occasion to express thanks, on behalf of the Society and the automotive industry, for the unusually generous response that a number of men made to our call for information on fuel. As a matter of fact it has been really wonderful. I think that all should be thanked for the efforts they have made, and for the freedom with which they have offered all the information they had in developing this report. I wish to thank also, on behalf of the members of the Fuel Committee, all those who have been so kind as to criticize the fuel report and the work of the committee and to help make it what it is. The Fuel Committee applauds Mr. Ensign for his efforts in solving the fuel question. It applauds President Vincent and his staff for what they have done in regard to the fuelizer. It applauds the International Harvester Co., Mr. Johnston, Mr. Arnold and all their coterie of experts for what they have done. It applauds everyone who has done anything whatsoever to help solve this problem, and I wish to say that if not one application is made of this hot-spot method based on the report, the committee will not feel sorry at all, for the reason that interest will be developed and through that a better technique.

The hot-spot method of manifolding was selected by the Fuel Committee because it seemed to be the only common ground on which we could arrive anywhere. There is the application of the spark-plug to a manifold which was involved in many patents and was a very difficult situation. After considering all the different ways, we selected the hot-spot method as a very practical and easy thing to carry through. The committee does not believe that it is a perfect system; it believes it is so much better than any average system that it is worthy of anyone's investigation.

An engine has been set up in the park here. It was loaned to the Society for the purpose of conducting a clinic and not an exhibition. It is not a stock engine; it is an experimental engine. It is here for the purpose of showing the pitfalls that an engineer will encounter in trying to apply the hot-spot system. Incidentally, the engine is so built that it is a sort of measure; it has very large intake manifolds, and everything is very favorable for a very bad result. We made a run yesterday, using ordinary manifolds, and got down to 0.585 lb. per hp.-hr. fuel consumption, which is not such a bad result after all. Notwithstanding the great fault we have to find with fuel, many of the faults lie in the engines that we build and recommend to our customers. In this engine the result that we get, 0.585, comes entirely from developing turbulence. Turbulence is the real thing we are studying. It is the tool that nature has given us to combat detonation; it is always the one royal road to economy and next to the compression ratio the most fundamental thing we have to deal with.

This meeting, considering the well-qualified men who are scheduled to address us, should go down in the history of the Society as one recording the greatest progress in a short time that was ever accomplished in anything we have attempted. I believe I can say without fear of contradiction that the agricultural industry has improved its internal-combustion-engine fuel-economy fifteen points since the Winter Meeting. Some have improved the kerosene performance to an extent that the gasoline interests will find it difficult to equal.

Dr. Dickinson, of the Bureau of Standards, has constructed a manifold around a Chalmers engine which uses normally a hot-spot manifold, and he has built a manifold of Pyrex glass. Moving pictures will be exhibited which will show quantities of gasoline traveling along the intake manifold, when we all think it is dry. This will illustrate the important fact that there is not an instance in which the manifold is dry. I think Dr. Dickinson's assistants will show that even at 500 deg. fahr. there is still some moisture in the manifold. That is a very important thing to know, and to record at this meeting.

Another thing which I am pleased to state is that Thomas Midgley, Jr., told me this morning that the information in regard to the theory of detonation, which Dr. Dickinson and I very fortunately brought from Europe, has been proved so sound that they have connected up the theory directly with fuel and can predict from the atomic structure of the fuel just what to expect from detonation, can figure out what combinations of fuel, what atomic weight and structure to put together to overcome detonation, and can forecast with accuracy the rate of flame propagation and the way the crest of the wave travels out from the spark-plug. That constitutes in my opinion the greatest scientific accomplishment in which our Society has had the honor of being instrumental.

Concerning the fuel report itself, such reports are rewritten several times so as to conform with the definite consensus of opinion, but there is always one statement that summarizes the subject. The statement that contains all there is in this report is that there are a few spots in the manifold where the fuel separates out and that, if these are made hot enough, the result will be satisfactory. That is all it amounts to.

You will have the privilege of seeing the International Harvester Co.'s exhibit, an engine running in which they have separated out and are burning 700-deg. end-point fuel, which is somewhat worse than kerosene, and doing it in a very clean manner. Another point, perhaps one in which there should be the most pride, is the diagram showing the temperatures ordinarily encountered in the exhaust at various loads and speeds. In connection with this diagram there is a curve showing the temperatures at which the fuel distills off. Thereby one sees the great problem. When the engine is running very slowly, the end-points of the fuel, or the points at which it will boil out, are higher than the temperature of the escaping exhaust, which is a very important thing and tends to show the limitations of the hot-spot method.

During the time we were developing this report, we were making tests with the pyrometer and were obtaining results, but we would scarcely reach one point before discovering something more to learn, and would then make another start. One of the men in our company

sold an engine of ours and guaranteed it for 45 hp.; whereas according to the books it only ought to develop 40 hp. We had to deliver the goods somehow. From the information in the fuel report, this engine should deliver normally 49.5 hp. We were then burning kerosene on hot-spot methods at about 42 or 43 hp. at the best, and normally at about 39 hp. By carrying this report to its logical conclusion, we were able to get the engine up to 46.5 hp. The engine normally develops 49.5 hp. on gasoline, and 46.5 hp. on kerosene. This illustrates what can be accomplished. The International Harvester Co. has gone even further and done much better than that.

CHAIRMAN CRANE:—The members of the Society should realize how fortunate they are in having had Mr. Horning as the chairman of the Fuel Committee. The amount of work Mr. Horning has done on this subject and the constructive effort he has put into it have shown remarkable results.

CAPT. R. W. A. BREWER:—The point that interests me most particularly in the fuel report is that it follows closely the lines along which I have been working for the last fifteen years. The committee has confirmed almost exactly certain specifications I laid out a number of years ago, which I considered at that time were the fundamental features of a hot-spot manifold. The feature of greatest interest to those engaged in manifold design is the curve showing the various temperatures in the system of an engine under various conditions of throttle-opening. An important feature has not been touched upon; no mention has been made of the metal to which the figures refer. It is evidently cast iron. There is some difficulty in arranging the various areas which are necessary to make a heated manifold conform to the figures given in the curves, when various types of metal are used; there are many designs of manifold in which aluminum forms an important part. The possibility and the immediate probability of metals of greater conductivity, such as copper, being used partially in the construction of manifolds, should also be considered.

I have found in conducting experiments on heated manifolds that one is very liable to be led astray by deductions made upon the block. This is because running conditions upon the road bring many other factors into account which might not be foreseen in a block test. Certain points in the report rather overlook the influence of road conditions; one, for example, is the cooling of the mixture after it has passed the hot-spot. I attach great importance to cooling the mixture after it has been initially heated, provided that any relation between the pressures in the induction system which is consistent with the drop of temperature between the various points of the system can be maintained. If that is done by proper design, the mixture can be maintained in the state in which it is produced in the heating element.

Another point in the report might lead one astray, and that is the statement that when idling the temperature is greater than at full load. One has to bear in mind the conditions of the particular engine. In some engines there is undoubtedly much conduction of heat from the water-jacket down the limbs of the pipe. This gives one a false or a misleading reading, perhaps, of the temperature in the pipe itself. The temperature at the location of the thermometer or other apparatus measuring temperature may not be a true measure of the temperature existing in the heating element. I have found in certain work a reversal of these conditions. For example, there is a tendency for the heating element to cool down when idling or running under light load for a considerable time. As an instance, in the early part of this year when the temperature was a few degrees above zero fahr., I ran a machine for 12 min. between 2 and 4 m.p.h. on the road on high gear. It continued running for 12 min. before the engine ceased operating regularly, and the cessation of operation was when the temperature in the heated element dropped to 110 deg. fahr. That temperature corresponds exactly with the temperature given in the report for that particular type of fuel. This is interesting, but does not show that the temperature rises under low-load conditions. I have discovered the interesting fact that the rise of temperature in the induction system, within considerable limits, does not seriously interfere with the operation of the engine under ordinary conditions; in designing apparatus of this kind it must be remembered that the design aims at low-load, half-load and three-quarter load conditions, which are those when the heating is most required.

CARBURETION AND DISTRIBUTION OF LOW-GRADE FUELS

BY O. H. ENSIGN

CONTINUED lowering in the grade of fuel obtainable compels automotive engineers to produce engines that will utilize it with maximum economy. The manufacture of Pacific coast engine-distillate with an initial-distillation point of about 240 and an end-point of 480 deg. fahr. was abandoned by the principal oil companies early in 1920. Utilizing this fuel efficiently through its period of declining values forced advance solution of some fuel problems prior to a general lowering of grade of all automotive fuels. Keeping prominent certain essential features of economical design in connection with carburetion, the problems have been:

(1) An absolutely correct metering for all engine speeds and throttle positions so that the proportion of air to fuel meets correct engine design
(2) Adaptation to changed engine design, especially in connection with the manifold, or the entire mixture path; even fuel distribution to all cylinders being of higher importance than limiting manifold depression, and cylinders not pulling together having caused the largest loss in many designs

Realizing that the lower the grade of fuel the more difficult even distribution becomes and the more disastrous the results from poor distribution, the best way to accomplish maximum economy and power is stated as being the provision of a carbureter producing a mixture meeting theoretical operating conditions under throttle control with economy and flexibility, then to design manifolds that permit use of this mixture by insuring even distribution to all cylinders. A carbureter used for the past five years is illustrated and described in detail, with supplementary performance charts, and a fuel converter is likewise discussed. Manifold designs are next illustrated and commented upon, the conclusion being reached that in some cases

a compromise between manifold depression and manifold turbulence on the one hand, and compression on the other, has made possible the use of extremely low-grade fuel and increased the power output to some extent. [Paper printede in full in the July, 1920, issue of THE JOURNAL.]

USE OF HEAVY FUEL IN AUTOMOTIVE ENGINES

BY H. M. CRANE

EMPHASIZING the necessity of persuading fuel manufacturers to improve the suitability of internal-combustion engine fuel by the mixture of other materials with petroleum distillates, and realizing that efficiency is also dependent upon improved engine design, the author then states that results easily obtainable in the simplest forms of automotive engine when using fuel volatile at fairly low temperatures, must be considered in working out a future automotive fuel policy.

The alternatives to this as they appear in the light of present knowledge are then stated, including design considerations. The principles that should be followed to obtain as good results as possible with heavy fuel in the conventional type of engine are then described. These include considerations of valve-timing and fuel distribution. Valve-timing should assist correct distribution, especially at the lower engine speeds. Manifold design should include a steady up-grade from the carbureter to the inlet valves and the manifold should be compact on multi-cylinder engines; the best manifold shape must be worked out for each particular engine. The final requirement in utilizing the heavy fuel of low volatility successfully is heat, but for good distribution the less the amount of heat used the better, because high temperatures reduce volumetric efficiency. [Printed in full in the August, 1920, issue of THE JOURNAL.]

ENGINE DESIGN FOR MAXIMUM POWER AND FUEL ECONOMY

BY C. A. NORMAN

DESIGN factors are considered from the thermodynamic standpoint only, which excludes several factors affecting power and economy.

The problem of air heating includes a consideration of its influence on pressure, the consequent lowering of pressure being counteracted to some extent by the resulting improvements in carburetion and distribution and by more rapid and complete combustion; the effects of delayed combustion, with a study of the thermodynamic conditions and possible improvements; and the results that are actually obtainable from lean and rich fuel mixtures.

Fuel economy is difficult because its factors conflict with those of power. The benefit of the expansion of any elastic working medium to economy is emphasized. Charts from previous papers, showing the ratio of air to fuel by weight, are referred to and discussed, best economy being obtained with mixtures leaner than those giving maximum power. The effects of air heating on fuel economy, the reduction of efficiency through friction losses and the various results obtainable from supercharging, are then enumerated and discussed. [Printed in full in the August, 1920, issue of THE JOURNAL.]

SAVING FUEL WITH THE CARBURETER

BY W. E. LAY

TWO series of tests were made in 1918; one to determine whether the mixture giving best economy and that giving maximum power is a constant quality for all conditions of speed and power output; the other to ascertain what effect changes in the temperature of the fuel-intake system have on the quality of the mixture which gives the maximum power and that which gives best economy. The standard United States ambulance four-cylinder engine was used for these tests, its carbureter having a primary air passage, a primary fuel-jet, an auxiliary air passage with an air-valve and a secondary fuel-jet, the manifold being cast integrally with the cylinder block and a curved riser conducting the fuel mixture from the carbureter to it. The testing methods and fuel consumption measurements are described. The results of the first series are shown on curves having mixture quality as abscissas and torque and thermal efficiency as ordinates, demonstrating that the mixture quality giving greatest power is different from that giving best economy, and that the mixture giving maximum economy becomes somewhat leaner as the power output is increased. Similar curves from the second series of tests, considering changes of temperature of the air entering the carbureter, warrant the conclusions that over the temperature range investigated an increase in the carbureter intake temperature means an increase in thermal efficiency and that the mixture giving best economy at a high temperature is a leaner mixture than that giving maximum economy at a lower temperature. These conclusions are then amplified, a further conclusion being that from 10 to 50 per cent more gasoline than is necessary may be used in operating. The ideal carbureter would supply a mixture giving best efficiency and automatically supply the necessary additional fuel only when the operating conditions require this extra amount of fuel. [Printed in full in the August, 1920, issue of THE JOURNAL.]

FACTORS INVOLVED IN FUEL UTILIZATION

BY P. S. TICE

FROM a laboratory examination of the controlling relationships between carburetion and engine performance still in progress, the general conclusions so far reached include fuel metering characteristics, the physical structure of the charge, fuel combustion factors and details of engine design and manufacture.

In every throttle-controlled engine, the variation in fuel metering for best utilization is inversely functional with the relative loading and with the compression ratio, but the nature of the fuel leaves these general relationships undisturbed. The physical structure of the charge influences largely the net engine performance and the order of variation of the best metering with change in load. Perfect homogeneity in the charge is theoretically desirable but entails losses in performance. With the least perfectly formed charge that will operate an engine, increased outputs result from a more nearly uniform distribution of fuel in the charge, even though accompanied by a reduction in charge weight. Considering available petroleum fuels, those requiring the higher charge temperatures for maximum utilization also possess the ability to ignite at relatively lower temperatures when mixtures suitable for engine use are made.

It should be possible to operate an engine continuously at open throttle, without detonation, on a properly constructed charge of any petroleum fuel proposed to date, with a compression ratio resulting in gage pressures including 75 lb. per sq. in., but an analysis of the failure to do this shows that preignition is the direct result of local overheating in the charge. Augmenting turbulence decreases local overheating and so appreciable inequalities of combustion-chamber surfaces must exist, and high piston-head and exhaust-valve temperatures contribute to a condition favoring detonation. Piston design, exhaust-valve and spark-plug electrode cooling are then considered, mention being made also of piston gas-tightness as being very important. Net engine performance is the square root of the brake mean effective pressure divided by the brake specific consumption, combining the cost of unit power and the amount of power obtained. Its value attains a maximum with mixtures only slightly richer than those resulting in the true minimum specific consumption. With manual throttle control, steady and consistent operation obtains throughout the throttling range when realizing the minimum possible specific fuel consumption but, so far, possible maximum utilizations cannot be realized in operation under governor control. These considerations are illustrated by charts, showing curves resulting from the experiments made. [Printed in full in the August, 1920, issue of THE JOURNAL.]

THE DISCUSSION

O. H. ENSIGN:—It is said that we are more or less children of environment, and I want to present this idea in connection with my paper. The work described has been performed under conditions that perhaps have not existed anywhere except on the Pacific Coast. The Pacific Coast has had available three grades of fuel; gasoline, so-called distillate and tops. The tops are simply what is left after completing the other refining processes, which might receive further treatment and form a large part of kerosene. The two grades available for general use were gasoline and engine distillate. Five or six years ago engine distillate was of a very good grade. It was of about 53 deg. gravity, Baume, and probably an initial distillation point of 175 deg. with an end-point of about 430 deg. fahr. About January, 1920, the oil companies announced that they would make no more engine distillates. The lighter ends were needed for gasoline and the heavy ends for the kerosene. The supply of crude oil had fallen to a point which made this necessary. The engine distillate had then reached an initial distillation point of about 240 deg. and an end-point of about 480 deg. fahr., so that in working out carburetion problems we have been forced to consider the conditions imposed by this engine distillate. Hence, we probably have made some slightly different assumptions in attacking the problem than would have been made under conditions where gasoline was the only fuel available.

As is stated in my paper, we have first considered that good distribution is more important than anything else. So we have made the assumption that a carbureter should give practically a straight-line mixture curve under all conditions of throttle control. Then we must get the engine to use that kind of a mixture. In starting most tractor engines the method used with gasoline was simply to prime the cylinder-cocks, and start direct on the distillate, because so many of the Western engines were larger than truck or automobile engines and would withstand such treatment. If the distribution was not good, it was troublesome to start an engine in that way and required much patience. Therefore, the correction of manifolds to get such distribution was absolutely necessary. In working at the carbureter problem we attacked it from an entirely new angle and tried to produce a satisfactory result with these fuels. In this we believe we were completely successful. The method selected was that of using the centrifugal force produced by a whirling mass of fluid. The drop of the pressure in the center of the mass is a function of the square of the rim velocity. The method of introducing the fuel and air was in such a manner as to attempt to eliminate all possible damping effects in the way of friction or capillary action. It has resulted in a fairly satisfactory device with which we have obtained a good amount of business.

CHAIRMAN CRANE:—Supplementing my paper, I would say, finally, that the greatest difficulty is to apply heat to correct distribution. The distribution must be made right at first and the heat merely used for vaporizing per se. The unfortunate thing is that the manifold must be short for the reasons I have stated, and at any speed that we may use there is no time to do any real work of vaporization of mixture in the manifold. The mixture leaves the carbureter and enters the engine in almost the same state, but in the engine there is an excellent opportunity to mix it thoroughly and apply it under the best possible conditions. As Mr. Horning said, the question of turbulence is of great importance, but each cylinder must first be provided with the proper proportion of liquid and air to get the desired result.

MR. HORNING:—At our 1913 Summer meeting Captain Brewer talked about the short inlet manifold. We were somewhat in doubt on the subject and I asked him how long the manifold should be. He said that he would not use any manifold. I think that statement has been of great value. I wish that engine cylinders were so concentrated and fuels good enough that we would not have to use inlet manifolds. We have bad fuel and must use manifolds. We are making the best of an evil by using them.

PROF. C. A. NORMAN:—If I understand Mr. Horning correctly, he believes that it is not common sense to depart from our present-day type of engine. Personally, I am in doubt whether the carbureting type of engine is not fundamentally unsuited to burn the present-day available fuel. My paper deals almost exclusively with this type of engine.

I am not sure that the Diesel and allied types of engine cannot be developed into successful automotive engines, at least for many kinds of work. Ten years ago I was connected with a Swedish company in Russia that has done extraordinarily courageous and important pioneer work in adapting the Diesel engine to marine service. It did considerable experimenting along the line of high-speed Diesel engines. On page 1644 of the

Gripper and Side Guide

Zeitschrift des Vereines Deutscher Ingenieure of Sept. 30, 1911, an eight-cylinder V-type 200-hp. marine Diesel engine is described. This engine was designed by three Swedish engineers, Derans, Lagersteen and Moosberg, for the company mentioned above. It weighed only 22 lb. per b.hp. It had an aluminum crankcase and several other automotive features. If the war had not intervened, it is not impossible that we would now have an automotive Diesel engine developed by Swedish engineers in Russia.

In talking to an American audience I cannot refrain from emphasizing that the present-day type of automotive engine is primordially an European product, developed by French and German engineers. I believe that in many ways it is utterly un-American in spirit. The great American contribution to early automobile engineering was the steam engine, and even Bernard Shaw lets this American steam engine beat the European gas engine. The steam plant, by its ability to handle almost any kind of fuel, its economy at reduced load and its superior maneuvering qualities, seems to me to meet the present fuel situation better than the gas engine in many ways. The new and promising revivals along this line which have been described in the papers presented before this Society at its recent meetings should be a source of great satisfaction and much interest to every uncommitted engineer.

My paper, while not deeply mathematical in character, is perhaps more suitable for study than for brief abstracting. I shall therefore mention only some of its salient facts. It is expansion that gives economy, not compression as such. In a more recent type of supercharging engine a high compression pressure is secured by pre-compression in the crankcase. To secure power, the clearance volume is made unusually great; hence the expansion ratio is small. There are some secondary influences, such as possibly reduced relative friction work, which make for economy in this engine. Fundamentally, however, from the economy point of view, the design is wrong. For that matter, this was found by early tests on Diesel engines using equivalent arrangements.

A second point is that the combustion must be rapid and should occur as far as possible in the clearance space. The thing that converts combustion heat into useful work is expansion. If combustion occurs late in the stroke, very little expansion remains to turn this heat into work. To waste fuel by late combustion, it is therefore not necessary actually to shift the peak of pressure out into some part of the working stroke. A peak in the clearance space, followed, however, by considerable afterburning, may cause both power and economy to remain perhaps 15 to 20 per cent below what might be obtained from the same mixture ratio. Hence anything that speeds up combustion deserves serious consideration. Double spark-plugs, turbulence and efficient carburetion are means to this end. Heating the air, or the whole charge, will unquestionably give reduced power with the engine on the test-stand. On the other hand it will also make it possible to operate the engine satisfactorily over a greater range of mixture ratio. It is a question whether this smoother general operation is not worth more on the road than a plus of test-stand power amounting to perhaps 5 to 10 per cent. In any case, within certain limits, the leanest mixture means the greatest economy and air heating, even up to 250 deg. fahr., is found to give improved economy by enabling the engine to run on leaner mixtures. Nevertheless I do not wish to appear as a champion of heated mixture as against the totally-heated manifold, or any other scheme that is found to be a better compromise. If I have talked and written about heated air, this is because I happen to have had the experimental facilities for investigating this particular possibility rather than any other. The fuel situation has however now risen to be a national danger, and it is only by frank acceptance of the best suggestion, no matter whence it may come, that this danger can be rapidly met.

INTAKE-MANIFOLD TEMPERATURES AND FUEL ECONOMY

BY W. S. JAMES, H. C. DICKINSON AND S. W. SPARROW

SUPPLEMENTING a "more miles per gallon" movement in 1919, a series of experiments outlined by the S. A. E. Committee on Utilization of Present Fuels was undertaken by the Bureau of Standards, in May, 1920, which included measurements of engine performance under conditions of both steady running and rapid acceleration with different temperatures of the intake charge secured by supplying heated air to the carbureter from a hot-air stove, by maintaining a uniformly heated intake manifold and by using a hot-spot manifold, fuel economy being determined for both part and full-throttle operation. A typical six-cylinder engine was used, having a two-port intake manifold with a minimum length of passage within the cylinder block, an exhaust manifold conveniently located for installing special exhaust openings, rather high peak-load speed and conventional general design. The carbureter was selected with the requirements in view of securing definite and measurable conditions of the intake charge and accurate measurements of the behavior of the charge as indicated by fuel consumption in pounds per brake-horsepower hour. Provision was made for an unusually complete series of measurements. These are described, the most unique being the construction of the tee portion of the manifold of Pyrex glass. Motion pictures of the manifold were taken during operation, but in only one run were the walls completely dry, and a surprising amount of directly applied heat was required to accomplish this.

The main series of runs was made with the exhaust-jacket manifold, in an attempt to determine how best to obtain low fuel consumption and rapid acceleration and how this result was influenced by changes in the amount of heat furnished the intake charge or in the method of supplying this heat. The fuel consumption tests were made at both full and half load at speeds of 650 and 1200 r.p.m. Full details of the tests are then stated, the results are presented in charts, and these are discussed. The results obtained are then summarized as follows:

(1) At constant speed, mixture ratio and power output fuel consumption in pounds of fuel per brake-horsepower-hour are independent of the temperatures and methods of heating the intake charge within the range tested

(2) The rate at which an engine will accelerate with a given mixture ratio, or carbureter setting, is markedly affected by the amount of

heat supplied to the charge and its method of application. Within the limits of this work, the greater the amount of heat supplied to the charge and the higher its temperature at the intake port, the more rapidly the engine would accelerate

[Printed in full in the August, 1920, issue of THE JOURNAL.]

THE DISCUSSION

DR. H. C. DICKINSON:—In connection with the report of the Fuel Committee which Mr. Horning presented, the committee thought it best to try to verify, by a definite series of experiments, a number of points raised in the report. To accomplish this the Bureau of Standards was asked to undertake a series of measurements.

A typical engine was mounted and equipped and a special manifold was constructed in an attempt to demonstrate whether there are or are not marked differences between the performances when the heating which the committee has recommended is brought about by heating the air before it enters the carbureter, heating the manifold all over more or less uniformly, or by heating a typical hot-spot. The results obtained in the series of measurements have almost entirely verified the predictions in the report and have gone considerably farther than the report in establishing numerical values representing the optimum temperature with which the mixture should be supplied at different speeds and loads, and in demonstrating to a certain extent the variation in economy produced by variation from this typical temperature. They have not demonstrated so markedly the advantages of the typical hot-spot over the method of the heated manifold. One thing has been shown which I believe is of considerable importance. It is that not only good operating conditions but good acceleration can be obtained with an economy mixture if the temperature is maintained at about the right point. It has been well known that we could secure good running conditions, but it has always been difficult to secure good acceleration conditions with a mixture of proper proportions.

In connection with this work, the first thing was to build a glass manifold. We built a manifold of heat-resisting Pyrex glass so that we could heat the manifold and see what was happening inside it. This manifold, at certain points, has a marked bearing on the present discussion. One of these points is that a very large proportion of the liquid fuel goes through the manifold in the form of liquid, at all ordinary temperatures. Another is that this liquid, contrary to our usual beliefs, very quickly collects on the surfaces of the manifold. In other words, a manifold in distributing fuel distributes it as a surface over which the liquid flows; that is, a very large percentage of the fuel, particularly under cold operating conditions, is distributed by surface flow on the manifold.

The question of distribution, if looked upon in that way, becomes a question of surface rather than volume design. Further, the lag, which we are concerned about as regards acceleration, is largely a matter of surface flow and not of the lagging of the fuel in the orifice behind the flow of air. That is, the fuel leaving the orifice follows the air somewhat closely, but the fuel flowing along the manifold requires considerable time. In other words, the fuel mixed with any given quantity of air follows that air several revolutions behind. Therefore, the question of proper distribution and also the question of proper acceleration are largely matters of conditions on the manifold surface. That illustrates, I believe, why the proper temperature of the manifold surface seems to be the very important point involved.

Another factor involved is the one Mr. Horning mentioned with regard to turbulence. If the fuel enters the cylinders from the surface of the manifold and not in the airstream, a large part of the necessary mixing must occur after passing the inlet valve. Therefore, the turbulence produced and the proper forming of the intake valve and its surroundings have a much more important bearing on the distribution and also on the rate of burning of the fuel than would seem to be the case if we looked at the problem from the other side.

There is one point in which I believe our experiments do not bear out the implications in the fuel report. The report suggests the spots at which heat should be applied in the hot-spot manifold. It suggests an excessive amount of heat supply at the upper portion of the tee and the "L" manifold. That proves not to be the place where, under most operating conditions, the heat is really needed. The fuel comes up the vertical lead, strikes the upper section of the cross tube and does not stay on that surface to any extent. But at almost all throttle openings and almost all speeds there is a very considerable building up of a pool of liquid near the lower bent surface of the tee. In heating the manifold with a blast lamp to secure proper operating conditions, it is found that much more heat is always required at the lower side of the horizontal member of a tee than is required at the top, which is of considerable interest. [Reference should here be made to comments by Mr. Horning and Mr. James on this subject printed on page 409 of this issue.]

A. M. WOLF:—What are Mr. Horning's views on the heating of a manifold, as brought out by Mr. Crane and Dr. Dickinson in the statement that the heat should not be applied on the top of the tee or the outside of the bend? According to the latest information, the heating should be on the inside of the bend.

MR. HORNING:—It would be folly in a report of this kind to undertake to go into details and tell the engineer just what to do. All the report intends to do is to set out the principle. I believe one company represented here will be able to explain how they are using the hot-spot principle. They go to the extreme of heating the whole surface, and yet they do not heat the air unduly.

NEIL MACCOULL:—How is the turbulence that is mentioned as being so much of an advantage secured?

MR. HORNING:—All engines have turbulence. The trouble with most engines is that turbulence is dampened out before it does any good. The problem so far as turbulence is concerned is to keep it going and not to allow it to die out. Most engines will produce it in a greater or less degree, but the shape of the combustion-chamber is so irregular that it is dampened out. In the engine that you saw running here, if we sand-blast the piston, run 10 min. and take it off, we get the whole story of turbulence. We can tell by the degree of advance of the spiral marks on the piston the intensity of the turbulence; that is the way we follow it up. In any cylinder the turbulence is created by the intake valve, the intake passage and other passages. The only difficulty is to get a regular shape. No combustion-chamber, in view of a number of considerations, should have any surfaces that run parallel to the opposite surfaces. My theory would be to make any form that will keep the surfaces from being parallel. All this must be taken with reservations. We have not yet reached the point

where we know the relative importance of turbulence and radiation. If there is turbulence over the exhaust valve and the spark terminals, we escape the danger of detonation.

A combustion-chamber like that of the average L-head engine is not favorable for turbulence. Bulges are bad for turbulence. We must study carefully to develop the maximum turbulence. In England they think that 130 to 150 ft. per sec. through the intake valve is the velocity of the incoming gas which gives the maximum turbulence, the best economy and the best mean effective pressures. Some think the piston speed is important, but they feel that velocity mentioned is the thing that really counts.

We must investigate what can be done to promote turbulence from the time the mixture enters the carbureter until the spark jumps. That is the whole thing. Some think that there is even a chance to produce and promote turbulence after the mixture has passed through the intake valve. One interesting thing is that with an engine having low compression, giving comparatively low mean effective pressures, we get good fuel economy. There is nothing that will do that except turbulence. Next to the compression ratio, connecting with it the volumetric efficiency, turbulence is the one means that we have left. We never could run engines at 4000 r.p.m. unless there was turbulence, unless turbulence had the wonderful effect that it has.

ELMER A. SPERRY:—An excellent opportunity is given in the curves appearing in the James-Dickinson-Sparrow paper to show just how much smaller engine capacity we get by heating the manifold. Heating is working in the wrong direction. We all realize that, of course.

THOMAS MIDGLEY, JR.:—Those who attended the Winter Meeting remember the very interesting account Doctor Dickinson gave of his discussion with Prof. Harold B. Dixon, of Manchester University, England, with regard to detonation. Professor Dixon had been investigating explosions in mines, which are very different apparently from explosions in cylinders, and had done some important work. Doctor Dickinson was familiar with all the previous work concerning knocking that had been done in our laboratory and with the various theories that existed, and he combined this knowledge with the results of the work Professor Dixon had done. He brought back to us a very interesting theory, for a part of which Mr. Horning was responsible. This theory struck us very forcefully at the time. The principle on which it is based was illustrated by igniting an explosive mixture in the near end of a pipe. The flame propagation does not progress at a constant velocity, but accelerates to a maximum in the form of a wave front which accumulates a high pressure. When this high-pressure wave strikes the side of the cylinder wall, it makes a noise called detonation. Mr. Crane, I believe, is convinced that detonation does no harm to the parts in the crankcase of the engine; it is simply annoying.

Since we had been investigating the knock for some time, we tested this theory to ascertain if it were sound. We had observed previously through a window in the cylinder-head that, when an engine knocked, the flame seen through the window was yellow. While running on the same fuel when the engine did not knock the flame was blue. We put an explosive mixture in a heavy glass tube that had a test tube placed loosely over one end, and then ignited the mixture at the open end of the tube. The breaking of the test tube showed that detonation occurred. The flame which was blue in the first part of the tube became yellow as it progressed. The flame in the combustion-chamber had been analyzed with a spectroscope some time previously. We found that, when the engine knocked, blue carbon bands appeared in the spectrum; when it did not knock, they were absent. Also, when the engine knocked, fine carbon came out of the exhaust pipe; when it did not knock, the flame was clear.

Let us suppose that a fuel molecule is hit by this wave front. The first thing the wave front must do is to break up this molecule. To do this, it must give energy to the molecule. This energy which is absorbed from the wave front by the fuel molecule is represented by lines called bonds. Each one of these bonds represents a certain amount of energy. After the wave front has broken up the molecule, something is left. We assume that this must be hydrogen. It follows that a knocking fuel is a fuel in which the ratio of the hydrogen to the bonds in the molecule is very high. The combustion of the hydrogen carries the detonation wave forward, and the energy required for the breaking of the bonds tends to hold it back; so, the more hydrogen there is, the more the detonation velocity tends to be reached and, the more bonds there are, the more the velocity tends to be retarded. The ratio of these two factors is a measure of the tendency of a fuel to knock.

We examined our data and compiled a table of fuels in the order in which they tend to knock. We had the ethers and the paraffins, the latter being the most important fuels because they comprise the materials we must burn in engines. Next came the olefines, the naphthenes and the aromatics; lastly, and with the least tendency to knock of all, as we had determined it, was alcohol. On the basis of the theory already outlined, we computed the relative excess energy available for detonation, or for supporting the detonation wave, and found that the order as thus obtained corresponded to that determined previously by experiment. Ether is the worst; paraffins are next; olefines are slightly better; and so on until alcohol, which is fine, is reached. We figured them in percentage. The ethers, which are worst from a knocking standpoint, were rated at 1000 per cent. On the same basis the paraffins were rated at 960, the olefines at about 860, the naphthenes at about 855, the aromatics at about 540 and the alcohols at about 600 per cent. We did not change the order because of the apparent discrepancy in the position of aromatics and alcohols. This discrepancy can be explained on the basis that the relative tendencies of the aromatics and alcohols to knock had been determined by blending and not by direct observation. We do not have compression sufficiently high to make either of these materials knock, except by blending with a fuel having a greater tendency to knock.

We analyzed the theory for an explanation of the fact that aniline stopped the knock. We took a standard kerosene and a standard gasoline, compared them in an engine and determined how much benzol was necessary to make the kerosene equal to the gasoline. Having thus determined their difference in the engine, we calculated as before that it should take only 3.5 per cent of benzol to make the kerosene equal to the gasoline; but, in the engine, it actually required 60 per cent. This disturbed us for a time but, when investigating a good theory, one surmounts difficulties of that kind. We assumed that the tendency of benzol to detonate is slower than that of the paraffins. It is reasonable to suppose that, as the wave passes through the mixture, it breaks down the paraffin molecules but not those of benzol, because the latter do

not decompose so rapidly. There would then be a region behind the wave front where the benzol is breaking down, but still is allowing the decomposition of the paraffin molecules to propagate itself as well as before. But if something could be done to the benzol molecule which would make it a little less stable than the paraffin instead of more stable, which we knew from other experiments could be done, we could get that effect. Consequently. to the benzine ring we added an NH_2 group, thus changing it into aniline, which we know is more unstable. We put in the 3.5 per cent of this material and found that it checked absolutely the calculated figure for benzol. I talked this over with Doctor Dickinson and he was inclined to believe that we had made a correct analysis. If we could determine how to obtain enough aniline to put into fuels, we would not need to worry further about engine knock.

FRED WEINBERG:—A question was asked as to how turbulence can be increased. I have found that turbulence can be increased in a practical way by reducing the intake-valve areas. The experiments made by the Bureau of Standards show that fuel economy is not benefited in any way except during acceleration by heating the mixture. There is however a somewhat novel way by which we can increase the fuel economy.

During the last three years an engine has been made in Europe which is extremely interesting. I have never seen a report of this engine in this country. It has given a thermal efficiency of 32.75 per cent. It is a carbureted job which is equal in thermal efficiency to the Diesel engines. The engine was not built for fuel-economy purposes, so far as I can ascertain, but with the view of accomplishing what we tried to accomplish in this country by supercharging. The people on the other side undercharged the engine; they undercharged at slight altitudes and thereby obtained the same effect that we gained in this country by supercharging. The engine is now more than two and one-half years old, has been run at various intervals and has not been appreciably changed. The idea consists in simply taking the charge up at a lower pressure than is usual and compressing it relatively more; in other words, the absolute compression is not increased but the ratio of compression to expansion is, and small intake valves are provided. Otherwise it is like the old Otto cycle, run on a slightly different principle. The name of the engine is the Bavaria. One of these engines which was shot down during the war was made the subject of a British report in 1918 and forwarded to this country. The British report on the engine is signed by R. Brooke-Popham, Brigadier General, Director of Research for the British Empire. I have since obtained from Germany a more accurate report on some more recent engines, and they show the remarkable thermal efficiency of about 34 per cent, which exceeds that of the Diesel engine.

CHAIRMAN CRANE:—The engines which propelled the Navy NC-4 in its flight across the Atlantic were of the high-compression type with small carbureters, thereby, to a certain extent, accomplishing the same result that Mr. Weinberg has described. The brake mean effective pressure of the engine was reduced, and a considerable gain in economy obtained. The original idea of the Navy was to use the Liberty engine at a lower compression but they found that it was not more reliable under those conditions or nearly as economical. We had intended, if we took up the question of dirigible design, to investigate considerably in this direction. It would be very interesting to study how far high compression and correspondingly rather low mean effective pressure can be developed with the idea of obtaining economy. In practice, in aviation engines it was possible in many cases to attain a fuel consumption of 0.45 lb. per hp-hr., on a high brake mean effective pressure, running up to 120 lb. This was usually done, however, by slightly holding back the maximum ability of the engine.

MR. SPERRY:—It is rather suggestive that the Diesel engine efficiencies, while they are much higher than that of the ordinary explosion engine, must work, it would seem, on a very much larger amount of air. The standard air of the Diesel engine is about 3 to $3\frac{1}{2}$ cu. ft. per min. per b.-hp.-hr.; whereas, nearly all the aviation engines are based on 2 cu. ft. per min. per b.-hp.-hr., which is a large difference.

Supercharging is of considerable interest. A good many years ago, Atkinson designed an engine in which he had an arrangement giving two lengths of stroke; one was used as a compression, which was comparatively shorter than the expansion stroke. He obtained an indicator card something like that shown in Fig. 1. The compression part of the card is at *a*, the ignition at *d* and the expansion line *b* went out to the point *h*. The base line of the card is shown at *e*, giving an adequate expansion ratio such as Professor Norman spoke of, but overcoming Professor Norman's difficulty, he having said that normally there is always a lock-step between high compression and the expansion ratio. This cycle would be a very valuable cycle if we could obtain it simply. We find we can do this easily by compounding the Diesel engine, and supercharging; by simply going out ahead of the Otto cycle and taking in air at superatmospheric pressure, really getting the Diesel on a basis of two-stage compression. I predict that in the future an engine based on that principle will be found to solve many problems.

If we take a Diesel engine card, Fig. 2, it is a rather thin-waisted card, but high. The compression is about 500 lb. per sq. in., auto-ignition; and then there is a constant pressure card flat at the top at *e* and with the expansion part *b* coming down, almost following the compression curve to the exhaust at *h*. Observing this curve, one peculiarity about it is that a large part, about 80 per cent, of the total length of the card to the right of the dotted line *c*, is low-pressure work; this part really shows low-pressure gases trying to do work in a high-pressure cylinder, exactly where they ought not to be required to perform. So, it is conceivable, and I have been experimenting along this line, that we can cut this card in two and let the complete Diesel cycle do its high-pressure work in the high-pressure cylinder, as it should, cutting the card on the line *c* in Fig. 2. The question then naturally arises, if we cut the card as indicated and start the compression at the point *g*, how can we reach Diesel pressure and Diesel temperatures? That is easy if we start high enough, reaching the point *g* at this particular point in the card. It is perfectly simple in this way to reach the same pressures and the same temperatures. Now, with this card we have the possibility of attaining the old Atkinson cycle indicated by the dotted, extended expansion line *b'* to the right in Fig. 2. To draw the new card as we get it from an indicator connected with a high-pressure cylinder of a compound

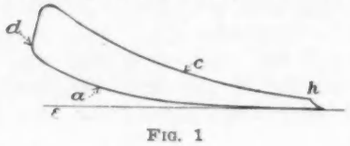


FIG. 1

Diesel engine, what we see is illustrated by Fig. 3. The supercharge line at a', being admitted to the high-pressure cylinder, makes a positive power stroke of the inhalation part of the cycle; that is, the inhalation stroke proper of the Diesel, whereas it ordinarily sucks in its air, is a power stroke. Suppose the pressure of this supercharge of air is 80 lb. per sq. in. In that way we get some of the power back that we have expended in the pump. Starting at this pressure supplied by the pump at g, we come up on the compression proper along line a, and reach our Diesel temperatures and pressures at d. The fuel is injected at this point. Now, we find that by suitably energizing the fuel and by changing the spray nozzle, solid fuel injection can be so constituted as to get either a flat line e across the top with a constant pressure that is shown in full lines; or, we can get a constant-volume card such as is shown in dotted lines, which materially contributes to efficiency, thus harnessing and utilizing to the full the dreaded detonation effect

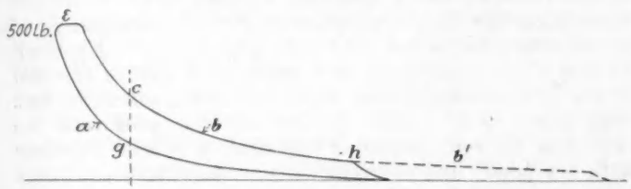


FIG. 2

of the heavy fuels in the Diesel cycle, where the engine itself is exactly suited to this work. Furthermore, we are practically unlimited as to speed, as it will be observed that the dotted line f is practically vertical, giving the ideal card for high efficiency on three counts: (a) high actual compression, (b) instantaneous combustion of the fuel and (c) very full and complete expansion of the gases. These pressures, which I predict are the coming working pressures, are easy to maintain as is instanced in thousands of successful Diesel engines, many of which run long periods without overhaul. When employing detonation, our pressures reach only to about 650 to 700 lb. per sq. in., whereas, at the Bureau of Standards, Dr. Dickinson has found pressures in the Liberty engine cylinder of between 900 and 1000 lb. per sq. in. The expansion in the high-pressure cylinder is indicated at b, Fig. 3, the transfer point into the low-pressure cylinder at h' and the continuation of the expansion of the gases in the low-pressure cylinder at b' running down much lower than in the ordinary Diesel, as shown also in the dotted lines b', Fig. 2. Engines have been constructed with the low-pressure to high-pressure ratio of 10:1, 8:1 and 6:1. Each has its peculiar properties and uses.

The transfer valve opens at h', at a pressure of about 200 lb. per sq. in. One would say that no Diesel valve is called upon to withstand any such temperature as these gases must possess; and this is true. A very simple solution of this difficulty was reached several years ago and this transfer valve never rises above a certain very low temperature, which is about one-half that of the exhaust valve in the Liberty engine, and requires practically no attention.

An aggravating detail in Diesel engines is the super-compressed air for spraying the fuel. It has been very justly denominated the curse of the Diesel engine, owing to the high complexity of the three-stage pump taken together with the refrigerating effect at the spray,

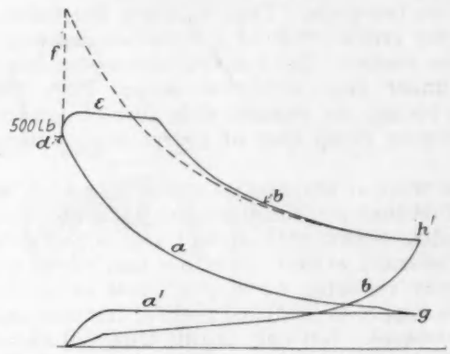


FIG. 3

exactly where we do not want it. The Diesel clearances are so small, however, that something of this kind is necessary for high fuel efficiency. These clearances range from 5 to 6 per cent and are of such ridiculously small capacity that it seems hardly worth building an engine centered about the small amount of oxygen present in these little crevices in the engine cylinder, making a super-abundance of chilled walls for the given cubical content. But with the compound we are able to change all this. For instance, the clearance space in the 10:1 compound is 40 per cent instead of 5 per cent; therefore, the volume-perimeter ratio is extremely favorable and insures perfect success of solid injection on the one hand, with all its attendant simplifications, while on the other it insures sufficiently large volume to expand easily down through two cylinders and exhaust at 15 to 20 lb. per sq. in. gage pressure, carrying out in the most complete manner Professor Norman's caution that, where supercharging is used, the expansion ratios should be increased in proportion. The small crevice constituting all the clearance that the ordinary Diesel is possessed of is a reason why it is often defined as a "mountain of cast iron with a little driblet of power coming out of one end." Its weight per horsepower is very high. For instance, the latest Worthington engine, a description of which has just been released, weighs 450 lb. per hp., and there are many engines that weigh much more. With our increased volume of clearances we get no higher pressures than are present in the normal Diesel, but we are enabled to "hang on" to these pressures for a very much greater percentage of the time. Instead of obtaining mean effectives to the crank of 62 to 70 lb. per sq. in. as in the Diesel, we are enabled to obtain between 300 to 400 lb. per sq. in. brake mean effective pressures, which gives us a very great increase in material efficiency. For instance, plans have been prepared for an engine weighing between 3½ and 5 lb. per b.-hp. at 1200 r.p.m. In the compound, although the mean effectives on the working stroke are low, it must be remembered that they are always to be multiplied by the cylinder ratio minus one, to get them on the standard basis of high-pressure cylinder performance. The very great gain in volumetric to perimeter ratio cuts down the cooling areas very materially in the high-pressure cylinder, and this is very greatly multiplied in the low pressure. This is about in the ratio of 27 to 8, giving very much less loss to the cooling walls and less cooling water required than in the ordinary engine.

The engine has two high-pressure cylinders separated by a low-pressure cylinder. The high-pressure cylinders are four-cycle, 360 deg. apart, alternately transferring to the single low-pressure cylinder, so that the middle

cylinder is two-cycle. Thus we have the unique condition of the crank effort of a four-cylinder engine with only three cranks. The low-pressure piston has a trunk on its under side somewhat larger than the high-pressure piston, the annulus thus formed constituting a supercharging pump that of course deals entirely with air.

It goes without saying that this engine runs with any kind of fuel that will run through a pipe, including gasoline, alcohol, benzol, etc. It will give a perfectly colorless and odorless exhaust on either coal tar or wood tar, in this way releasing about five times as much as the petroleum supply as available fuel for traction and small-engine purposes. Not only is this true, but through the entire elimination of the negative loop and all of the low efficiencies that a throttled engine is known to possess, operating, as it does, with almost a level line of efficiency throughout the entire range, this engine is capable of delivering to the axle between 30 and 40 per cent thermal efficiencies instead of in the vicinity of 50 per cent, which is about all that is now obtainable under service conditions. This will release another very large quantity of fuel, as only a fraction of the present amount of fuel will be required for the same performance. So taken all in all, I am thoroughly convinced that in our present-day work with the ancient explosive cycle with all its drawbacks, although we are doing wonders with it, we are working in the age analogous to that of Watt in steam-engine development. The great advance in steam engines since Watt's day has been in compounding.

Some English engineers are just waking up to the possibilities of compounding the internal-combustion engine. The British Admiralty has been working very persistently and in a large way in research work on Diesels. At a recent important Diesel engine session of the British Institution of Naval Architects and Marine Engineers, opened by an Admiralty paper by Commander Hawkes on Recent Advances in Diesel Engines, he mentioned the compound engine. In the discussion W. H. Wilkinson of Liverpool, who has given considerable attention to this subject, came out in no uncertain terms regarding this cycle as being the only avenue left for large advancement in combustion engines. He stated, in substance, that compounding in internal-combustion engines is even more important in their development than it had been in the development of the steam engine. He also said that it must be recognized that the engine at present is crude and that compounding alone is the line along which progress will be made. Commander Hawkes had referred to the mechanical complications. Mr. Wilkinson thought they were not inherent in the compound, and that it might be made as simple as an engine of the ordinary type.

The fact that this engine calls for a simplification and change in some features is in the direct line of progress and need not be in the slightest degree disturbing. I have lived to see practically every spindle in New England changed no less than four times; change and betterment is the order of the day and in the case of the automotive engine, with the present fuel situation, is most emphatically the call of the hour.

PROF. O. C. BERRY:—I recently made a study of the cycle used in the Bavaria engine. Theory seems to indicate that this engine is a fine one for full-load conditions. For part-load conditions one would expect its efficiency to fall below the efficiency ordinarily found in an Otto-cycle engine. Before considering it for automobile service, one should be sure to check over this point.

Some work has been done recently at Purdue University in an attempt to determine the temperature of the exhaust gases and consequently the temperatures available for the heating of the hot surface in the hot-spot, for the vaporization of the fuel. It seems, according to that work, that the temperatures vary with the speed of the engine, with the compression or load on the engine, with the timing of the spark and the richness of the fuel mixture. The first is very much the most important. With all conditions tending to produce the lowest exhaust-gas temperature, we were able to get the exhaust gases down to 300 deg. fahr. In making any report on the exhaust gases it would be well to include a statement of the speed of the engine, the compression or the load carried, the timing of the spark and the richness of the fuel mixture.

In connection with the work just reported by the Bureau of Standards, the Purdue tests reported at the January, 1920, meeting of the Society showed that the temperature of the piston-head is just about right for vaporizing the fuel most effectively. In consequence, if the mixture can be put into the engine barely hot enough so that the engine itself will vaporize it before the end of the compression stroke, high volumetric efficiency and high power will result. If the air that goes into the engine is too cold, improper carburetion results together with low power and poor efficiency. Starting with a very cold mixture and increasing the temperature, so long as the carburetion is improved both power and efficiency are increased. Too great an increase in the temperature decreases the power considerably and does not increase the thermal efficiency. The mixture temperature giving maximum power in the Purdue tests also gave maximum efficiency, and the mixture itself was fairly wet.

CHAIRMAN CRANE:—What counts is how the automotive engine is used. Its use is almost invariably not at full-load or full throttle conditions. The full-throttle condition rarely exists for a long enough time to become stable. A great part of the time the conditions are rapidly varying. Emphasis, therefore, is laid on the fact that the apparatus will be used by someone over whom the designer has no control, and it must be made easier for that person to operate in an economical manner.

The acceleration obtained with a cold manifold is, as stated in the Bureau of Standards' report, far too expensive to encourage to-day. With a cold manifold the car would probably climb a long hill somewhat better, it might go slightly faster on the road, but the time it would take to travel from New York to Boston would probably be less with a hot than with a cold manifold. The Society must certainly take into account, to a large extent, the psychology of the man who uses the machine. He does not like to have his car knock, and usually he will not let it knock. The car of to-day will knock in its most efficient condition, without a doubt. It ought to knock. Those who are accustomed to a Fifth Avenue motorbus would miss its knock if it were eliminated. But private owners would not drive cars that way. Therefore, we must try to encourage them, in some way, to accept the things that are required for economy by making it pleasant for them to use those things.

DOUGLAS L. ARNOLD:—We have experimented with the hot manifold somewhat along the lines of the Bureau of Standards' report. In Fig. 4 the carbureter is attached to the manifold as shown. The exhaust port of the center cylinders is at *e*: the intake port to cylinders Nos. 1 and 2 is at *f*. The carbureter is of the vortex type, the throttle

being at *a*. Intake ports Nos. 3 and 4 are duplicates of Nos. 1 and 2. Intake valves Nos. 1 and 2 are shown at *g* and *h*. The manifold is heated all the way around. We find that we do not heat the total air in the charge sufficiently to lower the maximum horsepower appreciably. In other words, the engine will do what we term 10,000 to 10,500 cu. in., which is not objectionable. That corresponds, in brake mean effective pressure, to about 79 lb. It is not particularly high. It will give a fuel economy of about 0.6 lb. per hp.-hr. on gasoline, kerosene or distillate, and will burn in a clean manner a distillate that has an end-point of 700 to 750 deg fahr., the first 5 per cent starting over at 400 to 430 deg., the Bureau of Standards' method of distillation. The last named fuel will knock considerably. Gasoline will knock, but very little.

Our theory for the delivery of maximum horsepower with the inlet manifold heated as stated, is that the fuel rides the wall and therefore insulates the air in the center of the airstream from the heat, this air not being heated sufficiently to reduce the volumetric efficiency to any great extent. To get the greatest efficiency out of the fuel, it is my impression that we must put it into the cylinders in liquid form and, after it is locked in and by the time ignition occurs, it should be in a vaporized state to the degree that it will expand in such a manner that the volume liberated after ignition will keep pace with piston travel, to give a good smooth-running flexible engine.

Turbulence is accomplished in the following manner: The fuel, when it comes down at *a*, rides around the throttle, comes up the side *b* and will ride around in the direction *e* or *d* as shown by the arrows in Fig. 4. When it starts riding around in this manner, it rides the pipe in a spiral, coming around the corner at *g* and *h*. It enters the intake valve with a more or less spiral motion and, when it goes into the cylinder, is in all probability whirling. This whirling is undoubtedly maintained during compression. This may be one way in which a large part of the knock is eliminated.

H. C. GIBSON:—Many years ago I operated and took indicator cards of an Atkinson engine. Its extra movement certainly gives very full expansion, as Mr. Sperry has mentioned.

Regarding Mr. Horning's discussion of flame propagation, if the noise we hear is due to the arrival of the detonating gases at the wall of the cylinder, there must be a minimum size of cylinder that cannot detonate and anything larger than that must detonate. If the larger cylinders, according to his theory, will always detonate, then such detonation can be overcome by putting in two, three, or four spark-plugs, thus reducing the distance that the flame can propagate from any one plug. Has that feature been considered. I do not admit that propagation detonation theory because we all know that the flame propagation rate of benzol vapor and air is fully as rapid, if not more rapid, than that of gasoline or kerosene. This fact should cause flame-propagation detonation when using benzol, but benzol removes knocking from an engine; that is, knocking is not caused by a flame-propagation or detonation wave.

F. C. MOCK:—A pyrometer is connected to the intake and exhaust manifolds on the engine Mr. Horning exhibited here, and the temperatures of both the exhaust and the intake manifolds can be read at different speeds and loads. The readings show clearly one basic tendency in that, although the exhaust temperature increases very greatly with the speed, the temperature in the intake part

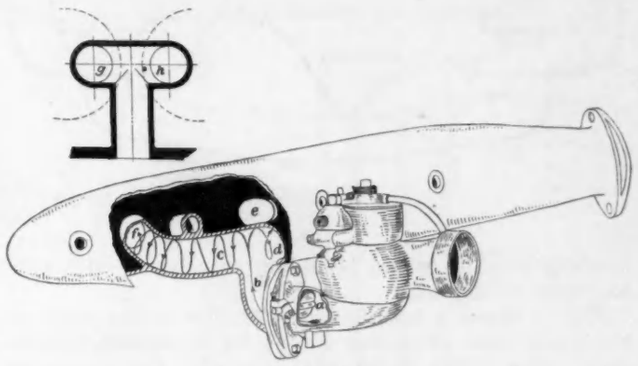


FIG. 4

of the hot-spot manifold does not vary more than 5 per cent of its absolute temperature throughout the whole range of engine speed.

In connection with Bureau of Standards' pictures, I call attention to the fact that, while a globule of gasoline slightly over 3/16 in. in diameter constitutes a full fuel charge for one cylinder of the engine, the accumulation of fuel shown by the pictures to exist in the intake manifold between the carbureter and intake ports amounted to something between 20 and 50 cylinder charges, or several tablespoonfuls at least. Experiments with mechanical mixers, compressed-air sprayers and the like have convinced our organization that this manifold accumulation cannot be eliminated by such means. At closed throttle, running under the same temperatures, the intake manifold was nearly dry but, upon quick opening of the throttle, the engine would not take up its normal operation until this wall flow and accumulation was established. The problem of obtaining smooth, flexible acceleration and deceleration under such manifold conditions is the greatest one in carbureter work to-day. Perhaps the chief difference between the older types of carbureter and the modern ones lies in the ability of the latter to accelerate smoothly and positively with a mixture of proper proportions for steady running by the use of devices which give a temporarily rich mixture during the time of acceleration.

With reference to engine cycles, it is unfortunate that most of the investigation and all of the present discussion refer to wide-open-throttle full-load operation. Passenger cars operate below one-third load 90 per cent of the time. At such loads the present cycle is deplorably inefficient. A further great improvement in the fuel economy of passenger-car engines is easily possible, as will be obvious from examination of the present cycle of actual average operation.

O. H. ENSIGN:—The question of manifolds is one in which we have had to take an active part, with the low-grade fuels on the Pacific Coast, both in the old distillate engines and in the recent attempts to convert the kerosene. The Bureau of Standards' paper has been illuminating as to why we have succeeded in our crude attempts to handle the so-called distillate when it is practically cold. This is not a theory. It is a performance that has been repeated again and again. Its aim is to accomplish distribution of distillate or any fuel when the fuel is cold. We are always obliged to start an engine cold, and the decrease of power and efficiency with acceleration when cold has by this means been very largely compensated, for I believe that with a very careful application of the type of device referred to crankcase and

FIG. 5

starting troubles would be eliminated largely on nearly any type of engine.

Fig. 5 shows a manifold developed into the plane of the paper, and illustrates a type for good cold-mixture distribution. The basic idea is to pick the condensed material off the wall and get it back into the stream at the point of diversion and in the direction desired. We must admit that there is a considerable film of condensed mixture along the walls on account of the average position of the throttle and the centrifugal forces that are bound to be set up with manifold velocities with this particular construction. The branch of the manifold that is calling for the mixture will get its full share, because the condensed fuel on the walls is kicked off by the deflecting choke into the airstream toward the source of demand. The engines using this manifold, designed for distillate, have been put to work recently on kerosene, and they perform exceedingly well. They even run remarkably well on perfectly cold kerosene with even distribution, above one-fourth load at governed speed. On these engines also we are using the fuel converter, which gives us ideal idling conditions and instant acceleration without any black smoke from the initial start up to full drawbar load in 5 min. The engine is 6½ x 8 in. and runs at 550 r.p.m. The manifold can be corrected for the lower-grade fuels in many ways. We have taken many manifolds recently that were built for gasoline and made them work on kerosene. They are approximating very closely their former drawbar pull. One form of siamese valve-pocket that has turned out fairly well is the one that is suggested in my paper.

I recently had occasion to make a six-cylinder car run on kerosene. The engine was a high-compression, running at 80 lb. per sq. in., 3⅜-in. bore and a rather large siamese valve-pocket of the conventional type. The manifold design was originally as shown in heavy lines in Fig. 6, developed into one plane. This would have been hopeless on kerosene; because of the design of the valve-pocket some cylinders would have gotten all the heavy ends and the others the lighter ends. While still using gasoline, we put the deflectors in as shown in light lines, and tuned the car up, operating on a grade that would give a gradual acceleration to 39 m.p.h. Then

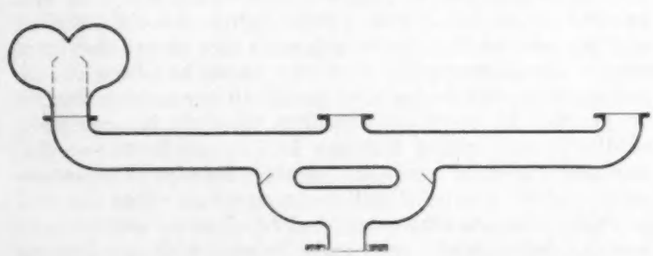


FIG. 6

we put in the bushings, shown in dotted lines, choking the ends from 1½ to 1⅛ in. and, with the same starting speed, on that grade obtained 42 m.p.h. on kerosene. This is a startling illustration of what can be accomplished by simply correcting distribution.

Before attempting to use lower-grade fuels with the converter it is not unusual to improve the distribution and, by turbulence, deflection and sudden chokes increase the output, thereby causing greatly increased economy. Sometimes the fuel consumption is reduced to one-half on road tests and, in using low-grade fuels, it is at times possible to get equal power, and sometimes even better power, than was obtained with the original manifold on gasoline. It is my belief that this is mainly brought about by having an even distribution to all cylinders. There is very little need, if any, for excessive fuel in acceleration if the distribution is made absolutely "square," and the general economy of the car will increase if this method is used. Poor distribution is a very large factor in aggravating the knock. If the distribution is poor, the cylinders thin in fuel will develop the knock while the rich ones will not have so great a tendency. A number of types of heavy-duty marine engine on the Pacific coast, for instance, were built for handling engine distillate. Many of them run very well without knocking when changed over to kerosene and some develop a serious knock. We are operating many engines successfully of 9¾-in. bore and 12-in. stroke with the fuel converter, with corrected manifolds. The converter succeeds in doing this because it separates the heavy ends that would develop the knock and converts them over into either slow-burning or inert gas; some of it is inflammable but some of it is absolutely inert.

I appreciate very fully the remarks made from time to time concerning the difference between the California and the Eastern gasolines and kerosenes. I am not certain that, since Jan. 1, 1920, the conditions mentioned still prevail. A very great change in the character of petroleum fuel on the Pacific coast and the methods of producing it has taken place.

In extreme cold weather, a very large proportion of the fuel passes through the firebox all the time. It must be cracked as well as converted somewhat into fog, for it is not at all difficult to start an ordinary automobile on Eastern kerosene and put it up to full speed almost immediately, with the whole plant well down below zero. There is no way to account for this except by cracking or fog processes.

Another phenomenon, that may not have been developed clearly in my paper, is that the volume of fire and amount of heat released is at its maximum under full load with this apparatus. In other words, the heat is so controlled that a definite heating program takes place from idling to full load. Under idling conditions, the heat is controlled by the thermostat to a desired high temperature; under load conditions, it is controlled by the characteristic of the apparatus designed to give a desirable working-load temperature to suit the grade of fuel used. The inherent characteristics of the apparatus, with the variation of the processes taking place under different temperatures of atmosphere and different loads, are exceedingly complex. Much time could be taken in further explaining the applications, but it is believed that these will be readily recognized by engineers versed in this particular art.

MR. WEINBERG:—Professor Berry made a statement

which is contrary to the facts as I know and possess them, with reference to the Bavaria engine, that the thermal efficiency of the engine decreases rapidly as the load is decreased. The figures, which are taken from about 55 tests, are given in the accompanying table.

TESTS OF THE BAVARIA ENGINE

Speed, r.p.m.	Brake-Horsepower	Brake Mean. Effective Pressure, lb. per sq. in.	Fuel Consumption lb. per hp.-hr
1,200	203	140.3	0.412
1,400	234	113.5	0.418
1,600	245	107.5	0.421

This table bears out my opinion as contrary to Professor Berry's.

MR. GIBSON:—What is the weight of that engine?

MR. WEINBERG:—I cannot make an exact statement of its weight.

MR. GIBSON:—It must be a heavy engine.

MR. WEINBERG:—It is extremely light.

MR. GIBSON:—I mean heavy per horsepower.

MR. WEINBERG:—Being an airplane engine it is extremely light per horsepower.

MR. ARNOLD:—There appears to be a misinterpretation of the facts. As I understood the matter, Professor Berry meant fuel economy at one-quarter load. What would that engine do at about 40 hp., at 1200 r.p.m., which would be one-quarter of its load? That is what I think Professor Berry referred to.

MR. WEINBERG:—I have given the brake-horsepower from 203 to 245, and the fuel consumption increases proportionately.

MR. ARNOLD:—This is what I have in mind. Consider a tractor engine governed at 1000 r.p.m.; it operates not at wide-open throttle or at maximum load most of the time but generally at between three-eighths and seven-eighths load. That means that we must have flat economy curves between three-eighths and seven-eighths load. The loads given in the table are practically the maximum loads for the engine at the speeds stated, on wide-open throttle. Automobiles are very seldom driven on wide-open throttle. To get economy on the road, there must be economy at partly-closed throttle.

MR. WEINBERG:—But the figures cited seem to indicate the opposite.

MR. ARNOLD:—We do not interpret light loads in revolutions per minute at those high speeds.

MR. WEINBERG:—At the slower speeds and smaller power output, the same relations exist. I maintain that the undercharged carbureted Otto cycle holds more than ordinary promise as to heretofore unheard of fuel economy and I submit it to your most earnest study and experimentation.

CHAIRMAN CRANE:—Professor Berry's statement was not about this particular engine but in connection with a theoretical investigation of the engine cycle. We have insufficient data to show whether he is correct or not.

In connection with this work, I would refer to an engine developed by E. C. Newcomb, because it has a pointed bearing. In Fig. 7 the piston is shown at the bottom of the stroke. The engine is developed as a single-cylinder crankcase-compression carbureter engine, the carbureter being on the crankcase. The mixture is transferred from the crankcase through an inlet valve into an exaggerated L-head combustion-chamber in which the spark-plug is located at the extreme end. This engine will show only about 0.7 lb. per hp.-hr. fuel economy

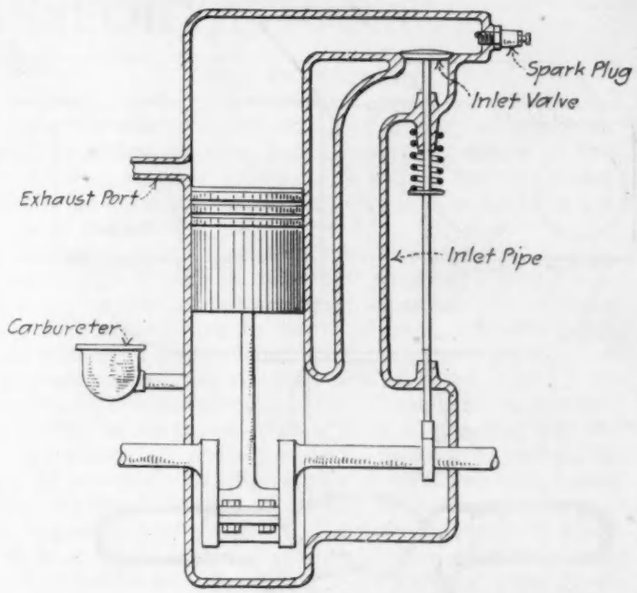


FIG. 7

at full load. The car weighs about 2000 lb., with passengers. The mileage has ranged between 50 and 85 per gal. of gasoline, depending on the road conditions. I know that this is difficult to believe. As a matter of fact, this car can readily compete with motorcycles on a basis of miles per gallon of gasoline. The reason is that we have an engine operating all the time at full compression, in which the designer has succeeded in obtaining a good burning mixture on part loads, by the shape of the combustion-chamber and by other features of design. The fuel-economy curve is practically straight. Fuel economy of under 0.7 lb. per hp.-hr. can be attained at one-third full load, and that is exactly where the average car is almost certain to operate on a level road.

I am glad that we have had so much from Mr. Ensign and others in regard to distribution, because, as all the papers have shown, distribution is certainly the fundamental basis without which we cannot expect to get economy with heavy fuel.

A. W. SCARRATT:—The problem of burning the heavier fuels confronted the tractor engineers several years before it affected the automobile engineers. We have done considerable work with reference to burning the heavier fuels efficiently and have recently carried on some experimental work on a 16-valve 4¼ x 6-in. four-cylinder engine, which has given very gratifying results. The manifold is nothing more than a hot-spot manifold, but we have tried to use logical reasoning in its design and aimed to accomplish exactly the things that have been brought out here. Mr. Ensign has illustrated a manifold which does some of the things that the manifold we have worked on has accomplished. But there are one or two ideas that we built into our manifold that go a step further. Fig. 8 represents the four cylinders and the manifolding. The exhaust manifold comes through the cylinder block and joins with the intake manifold. The exhaust gases, in coming across, pass through a jacketed portion *a* of this intake manifold and in doing so completely envelop a Y-shaped section of it and then pass out. The cross-section areas shown represent the three pas-

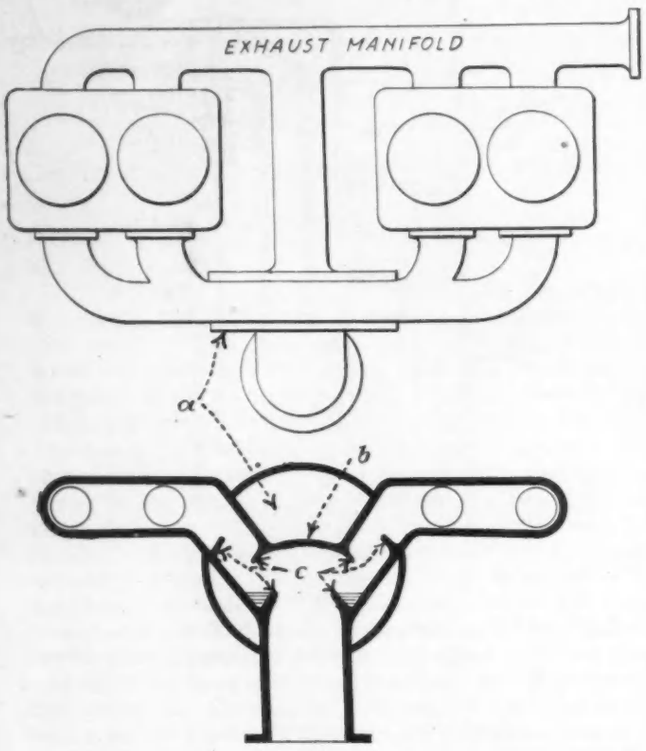


FIG. 8

sages of the exhaust gases surrounding the Y-shaped portion. The main inlet to the manifold is in a vertical position, and we use an ordinary plain-tube carbureter. The gases, in drawing up the main standpipe, pass through what is practically a nozzle, the area at its outlet being considerably smaller than the cross-sectional area of the carbureter. This is brought rather close to an umbrella-shaped plate, which is the most intensely heated part of the vaporizing chamber at *b*, and the edges of which hang down and obstruct the direct passage of wet fuel into the intake manifold. This has a deflecting effect upon the heavy particles of fuel and tends to throw them down on the bottom side of the main intake pipe on either side. It is an actual fact that, by providing additional dams at the two places *c*, we gather a small amount of liquid fuel in the two pockets; in other words, we prevent the raw fuel from going over. These pockets are out of the airstream entirely. They are heated in each case and act as a distillation-pot for the raw fuel. We have made tests with our engine equipped in this way, which show that we can run at full load on a fuel consumption of 0.562 lb. per hp-hr.; that is the best we have attained. We can easily get down to 0.6 lb. on kerosene. We obtain desirable temperatures at full load and when idling the intake manifold temperatures rise approximately 35 to 40 deg. fahr., which produces a good idling mixture. When an engine idles with the usual hot-spot manifold, it will soon begin to load up; the engine will then run unsteadily and very soon quit. We have idled this engine at a slower speed than we have ever been able to idle a four-cylinder engine before. It ran for periods of time in excess of an hour at 100 r.p.m. and, after having idled as long as that, I have snapped the throttle wide-open and the engine has picked up to its maximum load without missing.

We have put this manifold on truck engines and, in making a test with the 3½-ton truck, carrying a load of 8400 lb. over approximately a 26-mile trip, we have been able to get 6.5 miles per gal. of fuel, with a gross load of 17,300 lb., which is about 58.4 ton-miles per gal.

W. S. MEARS:—I was present at the Winter Meeting in New York last January, and the consensus of opinion was that the manifold was the wrong way to attack the problem. I believe that Mr. Kettering was representing that school of thought. Now I learn that the consensus of opinion is that we must find a way of dealing with the fuel molecule that will create turbulence.

A MEMBER:—I fail to understand why turbulence has so much bearing on whether hot air is used in the intake manifold or how the heat is applied. Turbulence seems now to be the big thing. Has it not always been the big thing? Whether we heat the intake manifold or put in hot air, or however we do it, does that affect the turbulence?

MR. MIDGLEY:—As I understand the intake manifold heating in the hot spot, it is largely a function to deliver the fuel uniformly to the cylinders. The primary function is not to vaporize the fuel, although whatever vaporization can be obtained is helpful.

CHAIRMAN CRANE:—The apparent inconsistency is very clearly explained in the Bureau of Standards report. The full-load economy was higher without the application of heat. Unfortunately, we are not dealing with that condition at all in road work. We are dealing with a condition of widely-varying loads and speeds. The minute the latter condition is introduced, the application of heat by getting the fuel into the cylinder more promptly and in a more uniform condition of mixture accomplishes economy that cannot be obtained with a cold condition. The two things are not inconsistent at all. One is the case of a block test where a steady speed is maintained and where the colder we can introduce the air the more power we will get and, evidently, with other conditions equally good, the higher economy, due to the higher power. The other is the road condition where the manifold is full of liquid, which may be dragged into the cylinder suddenly by opening the throttle and upset the correct mixture. What we must do for road work is to try to keep the manifold as free as possible of accumulated liquid, because it upsets the operation every time a sudden change is made in the throttle.

MR. MIDGLEY:—I will answer Mr. Gibson's question with regard to four spark-plugs. Four spark-plugs, or an increased number of spark-plugs, do cut down the knock very appreciably. I have had occasion to investigate this when called in to assist in the indicator work. We had the indicator element so placed that we could use four spark-plugs. Running on any one of three spark-plugs at a time we got a violent knock, as was evidenced by the sound, but on one particular spark-plug the indicator would not respond to the knock, showing that the wave of detonation was not passing across the piston of the indicator. Running on two spark-plugs that were adjacent, the knock was cut down slightly. Running on two that were diametrically opposed, with a greater distance between them but a shorter distance for the maximum flame to travel, the knock was cut down still more. When we ran on three spark-plugs it was cut down to almost nothing; when we ran on four spark-plugs the knock disappeared.

MOTOR-BUS TRANSPORTATION

BY G. A. GREEN

SINCE the Fifth Avenue Coach Co. of New York is the largest successful company operating motor-buses in this country, the author gives a rather comprehensive description of this company's systems and methods, stating the three main divisions as being the engineering, mechanical and transportation departments, and presenting an organization chart. Departments concerned with finance, auditing, purchasing, publicity, claims and the like, which follow conventional lines, are not considered.

The engineering, research, mechanical, repair and operating departments are then described in considerable detail. Six specific duties and responsibilities of the research department are stated and six divisions of the general procedure in carrying out overhauls for the operating department are enumerated. Regarding fuel economy, high gasoline averages from the company's standpoint mean economy, well-designed and maintained equipment, and skilled and contented operatives. After elaborating this subject, six definite ways and means that were adopted to secure and maintain high gasoline averages are stated.

The transportation department is then described and commented upon, the discussion then focusing upon the future possibilities of the motor-bus. In conclusion, the author comments upon the factors that have made this transportation system successful. [Printed in full in the July, 1920, issue of THE JOURNAL.]

THE DISCUSSION

G. A. GREEN:—Too often the manufacturer cannot get really accurate data in regard to the performance of his product. Very often it is badly cared for and abused and he cannot control this. His natural impulse is to strengthen the various parts to a point where abuse does not count so heavily. Of course, this means added weight and higher operating costs. The truth of this statement is evidenced by a marked lack of standardization as to rated load capacities.

In the motor-bus business, there can be no question as to the necessity of a research department. By this means we keep our machinery uptodate and thus guard against obsolescence. While a part of the engineering organization, our research department is available to all. Demands often are made upon it by departments whose routine work is not of an engineering character. It is not a luxury. Gasoline consumption experiments, for instance, indicate that we can effect an economy equivalent to approximately 18 per cent of our present fuel bill. In round figures, this would represent a saving of $90,000 annually. The changes necessary to obtain this economy are comparatively inexpensive.

The success of a motor-bus company depends largely upon the system employed for maintenance. Our vehicles are designed to cover 2000 miles of uninterrupted service. After this, they undergo a general overhaul. After a year's service, irrespective of mileage, each vehicle undergoes what we term an "annual overhaul."

We attach great importance to fuel economy. Our rising and falling gasoline averages represent the barometer on which we base our predictions. Excessive gasoline consumption means large fuel and repair bills with the prospect of still larger bills. We can accomplish a greater monetary saving by proper attention to fuel economy than we can with any other single item in connection with maintenance. From our viewpoint, high gasoline averages insure economy, well-designed and maintained equipment, skilled and contented operatives. Our experience has clearly demonstrated it is fully as important that we should instill in our employes the desire to give us good gasoline averages as it is that the machinery should be capable of doing so. The former presents far greater difficulties.

The outstanding features of the transportation department are (*a*) the large amount of time and money necessarily expended in the selection, education and training of the personnel and in record keeping; (*b*) the large and expensive supervisory force; (*c*) the complexity of schedule making and the far-reaching effect of this from the standpoint of income and that of the comfort and contentment of the transportation force as a whole; (*d*) the large volume of motor-bus traffic possible on streets already crowded with other kinds of vehicular congestion; and (*e*) the difficulties of winter operation.

Regarding future possibilities, the industry is absolutely in its infancy and the possibilities of improvement are almost unbounded. This is not true of other forms of surface transportation. The difficulties to be encountered in connection with motor-bus transportation are frequently referred to and stress is put upon the necessity for unified control, a highly-trained technical organization and a 10-cent fare. The last item is very important.

I have attempted to point out clearly that there are very marked differences between jitney operation and that of a company sincerely anxious to cater to a lasting trade, to give real service at all times. My thought was not to discourage responsible organizations from entering this field, but to show that there is more to the operation of a successful motor-bus company than the mere purchase of stock vehicles and running such equipment when travel is heavy. Such procedure can only result in failure and, if persistently followed, one of the most promising industries of modern times may receive a setback from which it will not speedily recover. No comparison is possible between Fifth Avenue motor-bus and jitney operation. Speaking in general terms, we lose money on at least 30 per cent of our total mileage. In wet and very cold weather our seating capacity is automatically cut in half and it frequently happens that an entire day's operation results in a loss.

In connection with our experience in the use of pneumatic tires for motor-bus transportation, for our double-deck buses carrying from 48 to 50 passengers, it is distinctly an experimental proposition. Many of the disadvantages are due to the pneumatics having diameters greatly in excess of those of corresponding solid tires. The disadvantages from a motor-bus standpoint are as follows:

(1) The center of gravity is higher and there is a greater possibility of overturning
(2) Passengers seated on the upper deck are more liable to be struck by overhead obstacles
(3) The impossibility of obtaining low-level platform construction
(4) The weight of pneumatic-tire equipment, which is in excess of that of solid tires of the same carrying capacity
(5) The decreased inside seating capacity because of the abnormal size of the wheel pockets

The advantages of riding on pneumatic tires are unquestionably greater. We cannot, however, expect any

great increase in speed, for this is controlled largely by the density of the traffic through which the buses must pass. Of course, there are many instances elsewhere where this does not apply. The pneumatic tire does permit of fuel economy and lower maintenance costs, but we are not yet in a position to issue exact figures. It seems clear that in our business the various economies would not by any means compensate for the extra cost. It should, however, be borne in mind that all of my remarks refer to the use of pneumatic tires in connection with our 48 to 50-passenger double-deck buses. The possibility of the successful use of pneumatic tires with single-deck vehicles of smaller seating capacity is an entirely different issue. I think this is a far more fruitful field.

I offer one or two suggestions in connection with the design of large pneumatic tires. It seems to me highly desirable that the overall diameters should approach more closely those of solid tires. This question has been vigorously taken up with the manufacturers and we have now in course of preparation several sets of experimental 10-in. tires, the overall diameters of which will be the same as those of the solid tires now employed. We regard this as a very interesting and important development. The reduced diameter of the pneumatic tire has wonderful possibilities from the standpoint of weight-saving. In this connection it seems better to consider the use of the demountable wheel rather than the demountable tire. The weight of demountable rims and fittings in general is appalling. From the standpoint of motor-bus operation, 8, 9 and 10-in. tires are out of the question. I think we all agree that it is desirable to eliminate weight which is unsprung. Above everything else, we should reduce wheel weight. In reducing wheel weights, it is of supreme importance that the amount of metal used at the rims be kept at a minimum. This is where the small-diameter pneumatic tire has such wonderful possibilities, for under these conditions the wheels really represent little more than hubs and they can be made readily from aluminum.

I believe that the S. A. E. might with advantage devote more time to the human side of matters of organization. At present its members concentrate almost entirely on questions dealing with design, material and the like. In our business we find that if we pay proper attention to the human side, bad design and material, although costly, do not necessarily mean failure. Clearly, where cooperation and team-work are lacking, all the engineering skill of all the best men in the industry will not make for success. By success I mean a condition which permits of satisfied workers and at the same time a fair return for capital.

H. M. CRANE:—Regarding Mr. Green's paper and his work, the Society should realize the value of information obtained from a man of his ability and position. It is very rarely that we have the opportunity to compare proposed practice and subsequent experience in the way in which he has been able to do, under the stimulus of a fixed income. The present situation in trucks is very encouraging, but the truck today is very far from being an efficient implement. The reason is that in most businesses the truck is a side-line. It is not the thing that makes money for the business; it is merely an accessory, and the matter of economy in operation is not necessarily of serious importance. In fact, a very successful truck might lack almost every good engineering point except the one important feature that it transported its load over the road, and that is what the owners care most about. They want the merchandise moved at any price. Mr. Green's corporation has a 10-cent fare and no one expects that this can ever be increased. I think that is a very valuable stimulus.

I have three questions to ask of Mr. Green. What is the weight per passenger of the present bus, fully loaded? What is the average yearly mileage? Mr. Green states that the buses are completely dismantled every year. What is the effect on the bus operation of the New York police regulations in which an effort has been made to handle the traffic on Fifth Avenue as a block, first north and south, then east and west, from the 34th to the 59th Street crossings?

MR. GREEN:—The approximate weight per passenger, taking the full load, is 200 lb. It is the total weight of the equipment plus the passengers, including a full supply of gasoline, oil, water, etc., divided by the number of passengers. The approximate yearly mileage of each bus is 30,000. With regard to the effect of the recent traffic police regulations, on the whole they have been of marked benefit to us. By close cooperation with the police we expect to effect further improvements. The chief detriment at first was that some trouble was experienced because the intervals between the north and south bound traffic and traffic bound east and west was disproportioned. Various changes have been made and the present arrangement works very well.

With regard to fuel, I said that our research department had discovered, during the past six months, means of accomplishing further economies totaling approximately 18 per cent and to apply those means would not be especially difficult, but 18 per cent is a most conservative figure. The controlling factors are as follows:

(1) The adoption of thermostatic hot-air control
(2) The adoption of a system permitting more complete control of idling speeds
(3) The employment of automatic instead of fixed spark-advance
(4) The elimination of gasoline-tank evaporation losses
(5) The introduction of a small quantity of exhaust gas into the inlet manifold
(6) The modification of exhaust pipe and silencer layout, this with the object of reducing back-pressure

PERPETUATION OF OUR HIGHWAYS

BY H. G. SHIRLEY

IT is essential that the question of why highways are not standing up as they should be investigated because of the doubt in many minds as to the advisability of the continuation of large expenditures for road construction. The Federal Highway Council investigated and it became evident that 80 to 90 per cent of road failures were due to the sub-base foundation. This led to studies regarding the character of the sub-base and what could be done to stabilize and make it such that failures would not occur.

The author discusses specific failures that were due to clay sub-bases and then considers in some detail the local soil conditions that must be dealt with in reference to what may be termed standard specifications.

A suggested road-building program is then presented, followed by the statement that great progress is being

made in the way of providing money and in the methods of road construction, but that we are falling back at a rapid rate in the number of miles being constructed in comparison with the number that should be constructed. [Printed in full in the August, 1920, issue of THE JOURNAL.]

THE DISCUSSION

H. G. SHIRLEY:—Every motor vehicle designed and manufactured means one more unit added to the transportation facilities of the country. The fundamental factors which make this machine effective are the correctness of its design, the quality of the materials and workmanship of the vehicle itself, the intelligence of the man who operates it and the type of road over which it is operated.

The preservation of our highways is a matter that is before the public at present and is exciting much interest. Many roads go to pieces every year and the public is becoming restive because it does not know why these high-priced roads fail. Before the advent of the motor vehicle certain roads stood up well and had a long life; but they were affected just the same as roads are affected today. Frost loosened the surfaces, but as the traffic was light and light-weight vehicles were used, the roads were not destroyed. The surfaces, after the frost left them, would consolidate again and give service the same as before. The same condition occurring each year would, however, finally cause the sub-base to work up into the surfacing materials and a mud-hole would result. Today, on the thin-surfaced roads of the country, when frost has destroyed the solidarity and the sub-base has been weakened by having been saturated with water, a very heavy load will destroy the entire surface, requiring replacement at great expense. The general public cannot understand why roads that cost so much are going to pieces and why it is necessary to spend, every spring, large amounts for replacement. Many say it is the fault of the engineers who designed these roads, but within the last 15 or 20 years a vehicle has come upon the highways of this country that was never thought of when many of these roads were designed. About 16 years ago we were designing for loads of 4 tons. The heaviest load that went over those roads in the country was 100 bu. of wheat on a wagon. Those roads were not designed to carry the additional loads that have been put upon them in recent years.

The road leading from Washington to New York was examined carefully and on a section in Maryland we found that the failures had occurred principally in the thawing and spring seasons when the sub-base was saturated with moisture. We found that the clay held moisture and was very unstable, that during the thawing season it lifted the surface, and that much of the surface was broken by an under force rather than an upper force. We found spot after spot of the road that had been destroyed by an action from underneath. The clay sub-base at these places was dug out, studied and tested. It was found that these clays contained a liquid and that, after this liquid was extracted, they would lose their plasticity and turn into ordinary soil. When treated with lime, the liquid lost its gluey or waterproofing characteristic, a sediment being precipitated that resembled burnt clay. A small amount of this untreated liquid would waterproof a large area. This study suggested the possibility of treating the sub-base of roads with some liquid that would break up the plasticity of the clays, make them less able to hold water, give them less capillary power, break them up and therefore obtain a more stable base at the season when the clays are the least stable.

It is very important that we should find out why roads deteriorate so rapidly. In cities where there is good drainage due to many pipes underneath the sub-base, the streets wear very well. In New York City, Broadway and Fifth Avenue both carry an enormous amount of traffic, but they were designed for this. It may be said that the road engineers of the country are not designing for the loads. The road engineers are just as wideawake to this question as anyone can be, but they are greatly restricted. I have gone to public officials and asked that I be allowed to make a traffic study to ascertain the amount of traffic that was using a certain highway. The State commissioner would ask me what it would cost. I would tell him about $3 per mile per year. He would say that was entirely too much, that we had 1500 miles of roads and that I was asking for $4,500. That traffic study, in my judgment, would have been worth $45,000 instead of $4,500, yet I could not get the appropriation to make it.

What we hope to accomplish by the study of the sub-base and why we need help is that we wish to put this sub-base problem in such shape that any inspector can go out on the job and ascertain by a simple test, just as he tests sand, gravel and cement today, exactly the type of road and of drainage or the treatment of the sub-base that should be used. We believe that in many instances the soil should be treated chemically; or replaced by gravel or some other substance; or that concrete walls should be placed on either side to keep the water out; or that perhaps piling should be driven down and capped with beams on which a floor can be laid which is designed to carry the load independently of the sub-base. Many unknown quantities enter this problem. We find many different types and different characteristics of soil. We have different water levels and mountains and hills that drain water down upon and under the road surfacing. All these things must be studied. We must find out what types of road and what sub-bases will stand and what their strength will be during the critical season when the sub-base is supersaturated with water or subject to frost conditions. In the Northern sections the frost heaves a road, cracks it up and breaks the surface. When heavy traffic comes over it, it mashes through, not being able to carry the load. In the Southern sections where there is no frost, the soil becomes saturated during the spring rains and in summer it dries and contracts and has almost a reverse action to that of frost in the North. These are problems that we are working on.

We know nothing whatever of the sub-base on which the road materials are placed. No study has been made of it. One may criticize and say that the road engineers of the country have been neglectful in their duty, but when we ask the railroad engineers what they know about sub-soils, they say, "Nothing." We find that hundreds of thousands of dollars have been spent in studying the effect of the heavy moving engine and cars on the rail and on down to the bottom of the ballast, but that not $1 has been spent in investigating the sub-soil. Until we shall have solved the problem of road foundations, we need not expect to have roads that will endure. I know of no body of men who should be more interested in this than you who have developed and constructed a motor vehicle that is so wonderful in the amount of work that it can do and the distance it can cover. It is peculiarly fitting that those who have thought out and developed this wonderful machine should lend brains and

energy to assist their brother engineers in solving this problem. It has more complications than most problems in engineering of which I know. I hope that this Society will appoint a member to work with the Committee on Sub-base of the Federal Highway Council, to assist in solving this big problem.

We are building roads under what we call standard specifications. That means that we are building roads 8 to 10 in. thick in the middle and 6 in. thick on the sides. The same thickness is used over the sands of Delaware, over the clays of Ohio, in the gumbo of Illinois and on the shale cliffs of Wyoming. There must be some difference in the bearing power of these soils. In Delaware, the sands provide perfect drainage; their bearing capacity is not so good. In Ohio, at certain seasons the clays are practically fluid. In Illinois, the gumbo is almost a liquid at times. In Wyoming the shale cliffs, impregnated as they are with oil and impervious to water, make almost a perfect foundation for a road and even a fair surfacing. Yet the same thickness of slab is used from one end of this country to the other. In one place more material is used than is necessary; in another place entirely too little material is used.

What we wish to do is to arrive at a point where we can design a road and say that it will carry 28,000 or 38,000 lb. from one end to the other, at the critical period of the year, without doing it any harm. Not until we reach that point will the transportation facilities of this country be put upon the same effective and firm basis that obtains in other industries.

I have seen roads in Connecticut, Maryland, New Jersey and Ohio, built along the most uptodate lines of concrete and other high-type roads, go to pieces to such an extent that, in a few instances, brush was cut down and thrown upon them to allow the vehicles to pass over them. A road is not a perfect road until it can give transportation facilities 365 days in the year.

We need at least 60,000 miles of national highways, 240,000 miles of State highways and 300,000 miles of improved county highways. This makes 600,000 miles of road that we should have. We should build that much within the next ten years. If we subtract the 200,000 to 250,000 miles now built, we would then have almost 350,000 miles of road that should be constructed within the next 10 or 12 years. What are we doing today? Only 2500 to 3000 miles of road will be completed this year and yet people say that we are making progress in road-building.

No problem is more vital to the American people to-day than this highway transportation problem, transportation as a whole. Our railroads are insufficient and it falls to your lot to manufacture a vehicle and to my lot to manufacture a road that will be auxiliary to the railroads. I hope you will cooperate. We want your assistance. The Bureau of Public Roads is doing everything it can. Everyone who is interested in this big subject is doing all he can, but the whole subject goes into fields unknown, into research. There is no laboratory at present equipped to go into it on the scale the situation demands. You can help us in the scientific studies you are so capable of making.

PRESIDENT J. G. VINCENT:—Mr. Shirley has so impressed us with the importance of this subject that Colonel Alden has been appointed by the Council to represent the Society in any way that seems best. In other words, the Council has instructed Colonel Alden to keep in touch with this situation and not only help but advise what action the Society should take.

W. E. WILLIAMS:—I cannot emphasize too strongly what Mr. Shirley has said about highway engineering. The roads are being destroyed, and the 5-ton truck is being blamed for it. To continue to sell 5-ton trucks, a sentiment must be created in the public mind that will cause the public to pay for these roads, so that heavy trucks can run over our roads and not destroy them. In Chicago it is being advocated that the 5-ton truck be not permitted the use of the streets. It has been said recently that the 5-ton truck is the enemy of the roads. Perhaps it is, but this road problem must be solved.

The members of this Society have confined themselves too largely to vehicles and matters connected with their industry, not calling them to the attention of engineers in other fields, such as civil and construction engineers. We will welcome such affiliation and harmonious cooperation. This is the direction from which the chief assistance will come in road-building. Motor trucks are meeting serious opposition because of the way the roads are being broken down. The civil engineer is the man most capable of investigating the road proposition.

We first thought the concrete railroad tie was the solution of the timber problem. The enthusiasm about it was extreme at one time and there was much talk about constructing a railroad tie that would be a permanent structure in the road-bed. But the factor of elasticity had not been considered. Shocks and vibration broke away the reinforcing from the concrete to such an extent that the concrete railroad tie was out of the question. The experience with the concrete tie in railroad service is somewhat similar to what we are encountering now on concrete roads with heavy trucks. There is a bending movement sufficient to loosen the concrete from the reinforcing, and in a short time the structure is gone. Another point, which Army men ought to be better able to understand than I, is that a concrete structure is shattered very much more by the shock of a shell than old masonry.

It is a question whether the solution of this road problem lies in some kind of structure that will accommodate itself to heavy loads. This clay-bulging feature, which was so sharply brought out by Mr. Shirley, is well known to the civil engineer, who encounters it in constructing abutments to bridges. It is not a new factor in the civil engineering world, and I am somewhat surprised that it seems to be new in the highway road-construction field. It is a problem which the civil engineer ought to be invited to share, or, automotive engineers ought to enter the civil engineering field and cooperate with them.

PRESIDENT VINCENT:—Your remarks are very pertinent. As I said in my address there are many things to do, and the officers of this Society are giving careful consideration to these various problems. They are trying to select the most important ones and direct their efforts accordingly, adding new activities as they find it possible to do so. The members of the Society are busy men, and there is a limit to the extent that we can encroach on their time for the various new activities. However, the question is being carefully considered.

JOSEPH VAN BLERCK:—I have traveled over a certain road between Toledo and Detroit and I know it well. About five miles of the road has gone absolutely to pieces. Frost has been accredited with the breaking up of roads, but that road never experienced a frost or a winter. The road was merely broken stone with a little surfacing placed on top. When the surface was gone, traffic dug

out the stone. Today that entire stretch of road is broken to pieces.

When we enter Wayne County, we find good roads. These same roads have been gone over by exactly the same trucks that are charged with the damage on the others and have, in addition, been subjected to heavy traffic since 1910. To-day their condition is good. Wayne County has an organization for the building of its own roads. It has its own gravel pits, washes its own gravel, and inspects every bit of cement used. The result is that this county has real roads, roads that stand up. Aside from a few cracks after a bad winter, which are immediately filled up with tar, there is no trouble. There are roads in Wayne County on which the surface is wearing off and which are becoming slightly rough, but the foundation is still there. Truck engineers are asked to design trucks that will not crush the roads, but it is my belief that if a few more sacks of cement were mixed with the gravel in the construction of the roads they would stand up.

W. C. KEYES:—The whole situation requires publicity and education. We might compile statistics as to the cost per mile of road-building in different localities, taking into account the cost of materials and labor at the time of building. The publication of such statistics would certainly expose irregularities and would tend to eliminate them.

E. B. SMITH:—I do not intend to argue in favor of concrete roads in particular. I do not know any of these roads which have been mentioned. There are many causes that make a concrete road go to pieces under heavy truck traffic. The mere fact that the aggregate in the concrete is not properly graded and proportioned may be sufficient to result in a weak concrete that cannot withstand truck loads. Also, the fault may be in the surface finish of the road. The specifications for road finish usually require that depressions and irregularities in a concrete road shall not exceed ½ in. from a straight edge 10 ft. long, laid longitudinally along the surface, or perhaps not more than ¼ in. from a 3-ft. straight edge. These are liberal allowances, but result in reasonably smooth surfaces. The impact from such irregularities is not usually very great at reasonable truck speeds. Until the time comes when we have in road-building a proper engineer-inspector who will enforce adequate specifications and see that roads are built according to design, there will be many road failures. A few more sacks of cement will not provide the whole solution for a poor road, but proper selection and use of materials, with rigid inspection at the time of construction should secure satisfactory roads.

W. E. LAY:—In a number of roads a characteristic crack is often seen. That crack has frequently occurred even within the first year after a new concrete road has been built. I have thought that it is caused by the fact that the new surface was put on an old road which was narrower than the new one, and that the old road-bed was thoroughly packed down and settled but that the overlapping part of the new road-bed, laid on the outside of the old road-bed, had not thoroughly settled.

FRED WEINBERG:—There is a road in Europe which was built in the administration of Julius Caesar. I inspected that road in June, 1914. It is in a remarkable state of preservation. I have motored over it for approximately 500 miles. This road has a foundation of brick.

ROBERT C. HARGREAVES:—The same group, whether old or young, which finds intense interest in the motor car, has only a passing interest in the road; therefore something must be done with this road problem to surround it with interest that will stimulate the imagination of the coming generation. I believe we must press home the real object of building a road to-day, which is to stimulate traffic over it, carry that traffic efficiently and best serve the economic needs of the area served by the road.

ANALYSIS OF FUNDAMENTAL FACTORS AFFECTING TRACTOR DESIGN

BY OLIVER B. ZIMMERMAN

THE farm tractor is finding itself among the most essential of mechanical agricultural devices; the industry is young, and controlling basic factors of design are not yet completely crystallized, nor has research had its proper share in the development. Some further factors of the author's earlier article on tractor plowing speeds are discussed in this paper. The earlier article, printed in the February, 1920, issue of THE JOURNAL, dealt chiefly with plowing data on the assumption that there was delivered at the drawbar of the tractor *a constant horsepower*. This paper starts with a normal condition of *a constant engine power* which is to be delivered to the crankshaft under governor control for any of the travel speeds analyzed. The tractor is considered as powered by a given brake-horsepower engine, this power being transmitted through sets of gears in which the net bearing and gear efficiency is taken to be 73 per cent. The drawbar horsepower would then be theoretically the same for various weights of outfits which are considered of equally good design and construction.

The effects of slopes and weights on the drawbar pull are then discussed at length and illustrated by charts. In conclusion, the need for research work to benefit the tractor and plow industries is emphasized. [Printed in full in the July, 1920, issue of THE JOURNAL.]

THE DISCUSSION

CORNELIUS T. MYERS:—Has Mr. Zimmerman any curves with reference to wheel diameter; also the rolling resistance?

MR. ZIMMERMAN:—The data I was able to find on that question are few indeed. Professor Moyer, of the University of Minnesota, presented a paper on Rolling Resistance of Tractor Wheels, in 1918, which went into the question of the wheel diameters. He found a very interesting advantage in large diameters. You can refer to *The Transactions*, Vol. 13, Part I, pp. 405-422. Sizes which would be useful to us in tractor design are not given.

MR. MYERS:—Will those experiments be carried on further to determine absolutely the influence of wheel diameter in various soils?

MR. ZIMMERMAN:—That is one of the research matters that must be carried out for the benefit of the industry.

CHAIRMAN E. A. JOHNSTON:—The development of the tractor has been neglected to a certain extent. We have all been busy applying our engineering ability to the development of automobiles, commercial vehicles and airplanes until a point has been reached where, unless we devote more time to the development of agricultural equipment, especially the application of power to agricultural equipment, we will have plenty of luxurious automotive equipment and food will be scarce before very many more years.

JOHN MCGEORGE:—I am much interested in the question of speeds. When I started to build industrial tractors many years ago, that question came up. Rather blindly, I confess, I protested against any speeds over 5 m.p.h. We were constantly bothered by people insisting on from 8 to 10 m.p.h. Those speeds were impractical. We have gone speed-mad. We should keep the speeds down. I protested last year against the speed idea as applied to the light automobile. We are going too fast altogether, and are absolutely wasting fuel and energy. I was very much pleased to hear the protest in such a clear fashion against excessive speeds.

CHAIRMAN JOHNSTON:—Speed as applied to automobiles and commercial vehicles is considerably different from speed as applied to tractors; any discussion of speed as applied to tractors will be very beneficial. It involves not only plowing but includes the travel speed of binders, mowers and other agricultural equipment which have been designed to be pulled by horses at a speed of from 2¼ to 2½ m.p.h.

H. C. BUFFINGTON:—I wonder how many of those present have actually seen tractors plow. They are plowing in the field right now at 1½ to 5½ m.p.h. The subject of speeds is very important to the manufacturers of tractors, for commercial as well as agricultural work. The tractor is gradually taking its place in the logging and oil fields, in road and various other kinds of commercial work. My personal opinion is that plowing below 3 m.p.h. is too slow.

T. S. KEMBLE:—It would help to clarify the investigation to call attention to the fact that in plowing and harvesting the important unit of speed is in acres per hour. In motor-truck work it is ton-miles per hour. In the automobile, it is miles per hour.

C. M. MANLY:—At the tractor plowing test, held during the meeting here, the thing that interested me most was to notice the difference in the condition of the ground that had been plowed at the different speeds. I noticed that the ground that had been plowed at 1½ m.p.h was very rough after plowing; that plowed at 3 m.p.h. was not so rough; and that plowed at 5.7 m.p.h. looked as fine as if it had also been harrowed.

Mr. McGeorge spoke about the error of trying to go too fast. We must save time. Time is the most fundamental element of life and accomplishment. We want to save petroleum and other products for future generations, but we want also to save some of the time of this generation. If more power put into the securing of speed will accomplish plowing and some of the after operations more quickly, we are justified in spending petroleum and devising new motive powers and new fuels for this generation, rather than sit back and let time slip by and save it all for the generations to follow.

MR. MCGEORGE:—My point was not the gain of absolute speed in miles per hour, but that we gain ton-miles or acre-hours by going more slowly and pulling more heavily. With regard to plowing, I agree that 5 m.p.h. is not an excessive speed. My point was more with regard to industrial tractor work. I want to economize fuel not by gaining lineal speed but by increasing the weight speed.

DAVID BEECROFT:—I have talked with several farmers in the West this summer, some of whom have tractors and many have not. Many of them say that they cannot get rid of their horses. That is the problem that seems to be in their minds. Many of them have bought tractors and still they have not been able to reduce the number of their horses as they expected. I saw ten or twelve of the bigger tractors that were taken out of service. The farmers used smaller tractors because they thought that by using them it would be possible to reduce the number of horses, owing to the variety of uses to which the smaller tractor can be put. The shortage of help on the farms this summer is a problem. Do we ever recognize that? What has been found out as to the requirements of the higher-speed vehicle to meet the various farm necessities, allowing the farmer to reduce the number of horses when he does install the tractor?

CHAIRMAN JOHNSTON:—A plow bottom can be designed to do the desired quality of plowing at almost any reasonable speed. In operating commercial vehicles the most important factor is the cost per ton-mile. In agriculture the most important factor is the cost to farm per acre, whether for plowing, harvesting, or other farm work. It is not altogether a question of speed; it is a question, in my judgment, of determining the most desirable and the most economical speed, so that the designers and manufacturers of implements can design and manufacture the various implements to operate economically and satisfactorily at that speed, whatever it may be. The question of whether one plow is pulled at 2 m.p.h. or two plows at 1 m.p.h. is not so important. The same amount of work is accomplished. In the first case the dead weight has been moved twice as far, and twice as many corners have been turned. The data at hand indicate that the higher speeds are not the economical speeds, even though approximately the same amount of work is accomplished per horsepower or per pound of fuel consumed.

It will be necessary for the engineers of this country to apply automotive power to agricultural equipment to increase the production per man and reduce the cost of production to a great extent; otherwise the cost of producing farm products, which include so many of the necessities of life, is liable to become prohibitive.

On the average farm the tractor can be used to advantage for drawbar and belt work only approximately six weeks in the year. The row crops and the implements to handle row crops, such as cultivators and planters, cannot be or are not hauled to advantage with the tractor of the present construction. The problem is the application in a general way of automotive power to agricultural equipment.

W. E. WILLIAMS:—We plan to put a plow or an implement into the field that will upset the farmer's whole plowing history and plan of turning over the soil. What we must do is to put out tractors to suit the plow that the farmer now pulls with horses, or there will be a serious check to the business.

MR. ZIMMERMAN:—Figs. 5 and 6 on page 135, THE JOURNAL, February, 1920, show clearly that for a given expenditure of energy at the drawbar the acreage accomplished is greater at lower than at higher speeds. The confusion occurs in our minds because we feel that with greater actual translation over the land at higher speed, we are accomplishing something, but field exhibitions

do not enable us to see the energy expenditure until it is analyzed. If we have a tractor pulling twelve plows at 2 m.p.h., that is plowing at 24 m.p.h; if we have a tractor pulling six plows at 3 m.p.h., that is plowing at 18 m.p.h., so far as area covered is concerned.

Referring again to the illustrations I mentioned, if anyone can figure anything out of this other than that with increase in miles per hour there is a decrease in acres per hour, I would like to find that person. The charts were carefully worked out for a constant drawbar pull. Against this, we have also the added rolling resistance which would still further decrease the possibility of accomplishment for a given expenditure of energy in acres per hour. It is very easy to see that, from 2 m.p.h., we drop far away in actual accomplishment with increase of speed. There is absolutely no mathematical or other gain shown by higher speeds of translation when received from equal energy expended.

Fig. 5, already mentioned, shows the result in very light soil; Fig. 6 is in heavy soil. Here is a decrease in accomplishment for an increase of speed with the same drawbar-horsepower expenditure. If we deduct again from this the effect of rolling resistance, however, granting that there is satisfactory footing, this curve will still further increase. Actual experiments show the effect on horsepower of increase of speed. The other point that was mentioned is whether the soil is better handled at the higher speeds. Of course, at the Ottawa Beach tests we were dealing with exceedingly light, sandy soils. With the average soil, which is sticky or clayey, we cannot get the nice pulverization that was shown here at the higher speeds. Moreover, the plows are not actually designed to work at those speeds.

Fig. 2, on page 132, THE JOURNAL, February, 1920, shows miles per hour and horsepower, based on careful experiments made and reported by Professor Davidson which in general, cannot be contradicted. At 2 m.p.h. a 14-in. plow takes 4.48 hp. in that particular soil. If we double the speed and make it 4 m.p.h., we have nearly 12 hp. Comparing 12-hp. with 4½-hp. expenditure, we find that for three times the expenditure of energy we are only doing twice the work.

THE OPERATING SPEEDS OF AGRICULTURAL IMPLEMENTS

BY PERCIVAL WHITE

THE question of the most efficient speed at which to pull agricultural implements in the field is causing more discussion than any other relating to the progress of the farming industry. Plowing and other operations are in certain cases being markedly accelerated as a result of the introduction of the tractor. Some tractor manufacturers are advocating almost a doubling of these former speeds.

In arriving at the merits of the question of implement speeds, consideration must be given (*a*) quality of results obtained, (*b*) operating costs, (*c*) first costs, (*d*) time saved, (*e*) labor factor and (*f*) plow design. The author interviewed a considerable number of tractor and implement manufacturers upon these points, and to make clear the elements involved he sets forth under each of these headings whatever there is to be said on the two sides of the speed question. [Printed in full in the July, 1920, issue of THE JOURNAL.]

THE DISCUSSION

E. A. WHITE:—One of the first and most significant of the high points touched upon by Mr. White is that he makes a very effective plea for a scientific study of the problems which affect the design and operation of our agricultural implements, and refers to the fact that in the past, and still today, we try to arrive at conclusions in this field by the wasteful method of cut-and-try procedure. He says that where experiments have been attempted along this line they seem to have been designed chiefly to prove the correctness of preconceived ideas rather than to get the truth of the matter, to go underneath the ground and obtain the facts in the case. He does not blame various manufacturers for this because he says that if these manufacturers do not look after their own products no one else will. I think that we will agree with Mr. White's conclusions in that matter.

I second Mr. White's plea for a thorough, scientific study of the facts involved in this case, even though, as he points out, the conditions are more numerous and varied than is usually the case where we try to deduce scientific principles. It has often been said that the conditions in agriculture are so complicated that it will be impossible to reduce them to fundamental facts whence we can take, we might say, scientific formulas or conclusions based on careful studies and use them as a basis for directing our design. Mr. White's opinion in this particular is that we have perhaps overestimated this difficulty because we have not dealt with it very thoroughly, and that there is a possibility of arriving at these fundamental facts. My own opinions in that matter concur with those held by Mr. White, who sums up his problems as follows: "In arriving at the merits of the question of implement speeds, we must take into consideration the quality of the results obtained, operating costs, first costs, time saved, the labor factor and plow design." I do not see why Mr. White limited the field to plow design. It seems to me it would be very desirable to include all implements that are operated with or by the tractor. He then continues and gives a very complete discussion regarding the advantages and disadvantages of high and low speeds, which he defines as below 2½ and above 3½ m.p.h. I was interested in getting his decision of what constitutes high and low speeds.

Mr. McGeorge is in favor of low speeds and said he would consider anything above 5 m.p.h. as approaching high speeds. Mr. White gives the pros and cons of high and low speed for operating expenses, which I will not review. They are those that I think most of us have heard. He discusses operating expenses and initial cost from the same standpoint. Then he takes up plow design and discusses that as affording a possible means of decreasing our draft as we get increase in plowing speed, and believes that it is entirely feasible to design a plow that will not show marked increase in draft at higher speeds.

In conclusion, Mr. White believes that to get efficiency in the production of crops, it will be necessary to go to higher speeds, and says that from talking with designers and builders of agricultural implements he believes the majority of them feel we are tending in this direction.

Some of them look forward with favorable anticipation to this change and others seem to dread it.

Mr. Zimmerman hit the core of the problem when he stated that, whether it is low speed or high speed, we are seeking the truth in this matter. That is what we are after. The ultimate problem is to produce crops. Too much of this discussion regarding the field speed of agricultural implements has been directed toward the plow; not that the plow is unimportant; it is our most important field implement; but by focusing our attention on the plow we have forgotten a number of other factors. There are many factors that have not yet been brought into this discussion, so far as I know. We are interested in power, and in this discussion we are liable to get back where the tractor industry was a few years ago when the tractor was sold primarily as a plowing implement and all the other things which it was to do were ignored. If we are to see power farming reach its maximum possibilities, we must take into consideration ground cultivation, harvesting, field hauling and all those factors which enter into the production of food.

I emphasize Mr. White's plea for a scientific study of the factors involved in the speed of operating agricultural implements. There is much that can be gained from that. It is a problem which lends itself to exact and scientific studies and when we get enough of them we can evolve general laws that will be of great value to us. But we should be very careful that we do not fall into the error of drawing final conclusions from insufficient data. I am much in sympathy with all the work that has been presented upon this subject to date, but for my part I am nowhere near ready to come to a final conclusion regarding the facts in the case. What is the situation? All the experiments that I have seen reported to date have been conducted with plows. They have been conducted with plows that have been designed fundamentally for the speed of horse-drawn implements. There have been a few minor changes to adapt them to the tractor but, so far as I know, all the data thus far have been confined to these essentially lower-speed plows. From my study of the plow problem I am convinced that it is possible to design a plow which will not show much marked increase in draft at higher speeds.

When we get through with the plow, let us consider soil-preparation implements. Here we have essentially not as good a footing for the tractor. I have heard reports of experiments conducted where the drawbar pull which a tractor could exert on plowed ground was far less than that it could exert on the firm footing when it was plowing. We are encountering the fact that probably our drawbar pull of percentage of weight that we will get will be very much limited, compared with what we get for plowing. This means that there is another limiting factor for the possibilities of the tractor.

When harvesting crops we get good footing, but if we pull two binders we complicate the problem of operation. Farmers may not desire to build 15-ft. gates to allow the passage of 12-ft. swath binders and the like. They may not wish to go to the trouble of turning the machine around every time they go through a gate. There are a large number of factors in this speed problem which we must consider.

Another fundamental factor in the whole thing is that the farmer is showing a tendency to limit the size of the equipment which he wants one man to operate. If the percentage of different-sized tractors at present are any indication of what the farmer is coming to, we must consider the four-plow tractor. The four-plow outfit is about the maximum size that he wants to operate, and by far the larger percentages of tractors sold at present are smaller than four-plow machines. It may be possible to educate the farmer to use a larger machine, although he will be very much afraid of the additional weight that will go into that larger machine, and very hesitant about putting that additional weight on his soil. He may plow, but he will not do harrowing and things like that with it. If, for purposes of argument, we say that the four-plow machine is the largest that is practical for general agricultural conditions, and the majority of machines sold will be smaller than that, and if we limit the speed to 1½ m.p.h., the possibilities of power farming are immediately circumscribed by that size and that speed. If that size is the limit, the only other outlet for increasing the ultimate efficiency of power farming, which will enable one man to do more work in a given time, comes in increased speed. There is too much at stake for power farming in the possibilities of increased speed for us to draw final conclusions from insufficient data. It is the one outlet we have for ultimately increasing efficiency after we limit the size that will be practical for the farmer.

Let this good work go on. The sooner it can be determined what will be a practical speed from all standpoints, the better it will be for all of us. I believe that careful investigation is covering all factors in the case with new designs of implements which will stand up at these higher rates of speed and give the best work possible.

And these higher rates of speed are necessary before we can come to this conclusion. I believe that we will never get the final answer with the equipment which we have available at present. The ultimate efficiency of power farming is at stake in this discussion of what speeds we will ultimately adopt; but that is too large a subject to handle without the most thorough discussion and the most exhaustive field experiments.

JOHN MCGEORGE:—Mr. E. A. White fairly put the match to something that has been in my mind for years. Consider the expression "power farming." I have been rather afraid of saying what is in my mind from the tendency people have to indicate that we must go slow. Here is something not far distant in the future that I want considered. We have been designing all farm implements to suit the horse. When people learn to walk they use rectilinear motion; when they moved on the water they first used rectilinear motion; when they tried to fly, they first tried to use the wings of the bird. Man has always returned to circular motion. We have come to it in driving the automobile; in any vehicle we have come to the wheel. We have come to the screw in aviation, and to the paddle wheel in water. Why should we stick to rectilinear motion or the motion of pulling the plow as the horse did? This question of power farming strikes very much more deeply than some of us realize or than can be determined at present.

This question of research was discussed only recently by the American Society of Mechanical Engineers in St. Louis, and is being very much emphasized. I hope the good work will continue. Here is one direction in which I would like to see research advance. Is it not possible, since the plow limits us in many ways, to dispense with the plow? The object is not to plow the soil; it is not to turn the soil in furrows. The object is to pulverize the soil, to expose the new surfaces to the atmosphere and to prepare them generally for seed. Plowing is only one step in that direction. Plowing es-

sentially necessitates traction; so we have the tractor.

We take the traction of the wheels of a traction engine to pull a reaper. The speed of the engine is slowed down to conform with that of the wheels. Then, we take traction on the wheels of the binder and speed up to the cutting speed. Why do we not dispense with traction entirely? Why do we not take the speed of the engine right over to the implement itself? In other words, why do we not use the traveling powerhouse, which can be used in any part of the farm under any circumstances, instead of the tractor?

W. E. WILLIAMS:—Mr. McGeorge has brought out a point that the agricultural implement maker has long had under consideration and is equipped to supply apparatus for. The company with which I am associated has developed a long line of implements—mowing, harvesting and other agricultural machines—wherein the power of the tractor operates the cutting mechanism directly without having the power translated into traction and again into cutting movements. In the harvesting machines there are, directly coupled behind the tractor and directly operated by the power of the tractor, several different sickle bars cutting as wide a swath as any one can desire.

As to the idea of doing away with the plow, hundreds of thousands of dollars have been spent in machines that directly pulverize the soil with rotary motion. Many thought this was the end of the plow, but it was not. Those machines were born, lived and died in a very short period, notwithstanding the fact that it is desirable to have a thorough and deep pulverization of the soil. The fact is that it is necessary to turn the bottom soil up and the top soil down. All these developments revert to the situation of progression from the old method to the new. The implements developed for the horse must be considered and no wide radical step can be taken immediately or accomplished, perhaps, within the lifetime of any of us, as the horse is destined to stay with us.

CHAIRMAN E. A. JOHNSTON:—I agree fully that we should obtain all the available engineering data that will enable us to apply automotive power to agricultural equipment. I also agree that it is not good practice to transmit the power from the engine of the tractor to the ground, and then up through the driving-wheel of the implement to the implement. That is an intermediate step necessary in adapting the tractor to the horse-drawn implements now in the field. The application of automotive power to agricultural equipment is a broad and very important subject. I cannot too strongly impress upon automotive engineers the necessity for active work in this field. We have talked about it for some time; now is the time to do something about it. The average farm of 100 acres generally has five horses. It requires the product of approximately 4 acres to keep each horse; so, approximately 20 to 25 per cent of the acreage of a farm which is operated by horses is required to maintain the horses.

NOTES ON POWER FARMING

BY R. W. LOHMAN

THE paper relates to some of the methods and apparatus which can be used to advantage in large-scale farming operations. The laying out of a production program, the transportation of men and supplies, special implements for raw-land preparation, tractor dynamometers, large tractors, special plowing and tilling implements, four-wheel-drive tractors and road haulage are discussed.

An operation chart applying to an area of 40,000 acres is first presented and analyzed. Regarding hours of operation, the author maintains that with a suitable organization and proper selection of motive power and implements, tractors can be kept in motion 20 hr. per day and gives a time-table.

Consideration is then given in some detail to the problems of electric lighting, the implements used in raw-land preparation, the power required for various operations, types of tractor construction, plowing and harrowing, harvesting, hauling and tractor-train schedules, the whole being copiously illustrated.—[Printed in full in the August, 1920, issue of THE JOURNAL.]

THE DISCUSSION

E. H. SCHWARZ:—Are there any brakes on those trailers? How are grades provided for?

R. W. LOHMAN:—Every other wagon is equipped with a brake and a rope runs the entire length of the train; so, a man traveling on any trailer can take up the brakes.

C. T. MYERS:—The value of the speed of the small tractor has been set forth very forcefully; also, in the charts which we saw today, we noticed that the horsepower increased more rapidly than the speed. The important thing to focus on is the reason for the increase in horsepower per mile per hour. I think that an investigation would show that it is due to shock load. The impact of the various parts of the machine on one another, which occurs when the tractor is going over the ground, absorbs energy. It is the same problem with which automotive engineers have always had to contend. Their chief troubles have been due to shock load, and the loss of power due to this load has been reduced to a small amount by careful design. It will be necessary, therefore, in reducing that loss, to cushion shock load, as is accomplished by tires, springs, and more or less chassis flexibility, in the automotive field. Tractor engineers can profitably devote much time to the consideration of cushioning shock load.

Lubrication is another feature which will need to be very carefully considered when speeds are increased. All mechanical movement depends upon proper lubrication for its efficiency, and the life of all mechanisms is also dependent upon it. Anyone who scans the tools used by the farmer will be impressed at once with the fact that there is inefficient lubrication in many cases and often an absolute lack of it. Not only is there often little or no lubrication, but wearing surfaces are exposed to both dirt and oxidation. The development of these points, covering the absorption of shock load and the proper lubrication of all parts, if carried to a logical conclusion, will help as much as any others to solve the question of speed for farm equipment.

C. M. MANLY:—We know that it takes relatively more power to run a railroad train fast than it does to run it slowly, but we have been willing to pay to save time. It comes back to the matter of time, and proving by charts that it is more economical to work at the lowest horsepower requirement does not satisfy the entire equation. We figure that the tractor will be used only 44 or 45 days per year, partly due no doubt to the weather and the

season. That emphasizes the importance of time. Time is a function of acreage-speed, and acreage-speed is a function of power.

CHAIRMAN E. A. JOHNSTON:—We agree with Mr. Manly that time is an important factor. Time is a factor of economy and not altogether a matter of speed. A tractor may pull two plows at 4 m.p.h., which can be termed a high rate of speed, or four plows at 2 m.p.h., which can be termed a low rate of speed, and accomplish the same result with better economy.

Engineers who have been connected with the implement industry for some time are adverse to high speeds in a general way, but there is considerable confusion with reference to what is considered high speed. A speed of 3 m.p.h. is a desirable speed for nearly all implements; with plows and other implements work of satisfactory quality and quantity can be accomplished at that rate. There is a desire, however, on the part of most engineers connected with the industry to head-off speed advocates who recommend a speed of 5 to 7 m.p.h. These speeds are destructive; they are almost impossible from an operating standpoint. It is difficult to obtain operators who will endure the operation of a tractor at such speeds, and they are undesirable from many other standpoints. As Mr. White states, it is a question of determining the most desirable speed and then to standardize on that speed in such a way that implements can be designed and manufactured to work economically and accomplish a good quality of work at that speed, whatever it may be.

SHOP PRODUCTION-CONTROL AND ACCOUNTING SYSTEMS

BY A. G. DREFS

IN the automotive industries there are four major divisions of activity, manufacturing, financing, engineering and sales. The first three and especially the first two are today real problems. There have been no real sales obstacles.

The paper discusses production-control, especially the routing of materials, and systems of accounting pertaining to shop production. They cannot be separated without destroying the effectiveness and efficiency of one or both.

The divisions of the production department, the planning department, scheduling an order for production and preparing cost data are then considered at length.

The distributing of overhead expense and the securing of complete factory costs are then fully discussed and illustrated by diagrams. [Printed in full in the July, 1920, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN HAROLD EMMONDS:—Mr. Drefs has touched upon a subject that everyone ought to think and work over, but it has been my observation that most people dislike it. During the war I observed the operation of twenty-three plants that were building aviation engines for the Government under my department; also a great many parts plants. While I knew very little about the matters that Mr. Drefs has spoken of, I could readily see that there were many others in the industry that were in very much the same boat, and that hardly any of the different institutions had similar ideas about how to manage such things. It seems to me that some fundamental things might be and must be agreed upon at some time, because of Governmental interference with the accounting departments of industry. This is assuming large proportions; it is something we did not need to consider before the war. Including the methods employed in settling Government contracts, those employed by the treasury department in figuring the income and excess profits taxes and the changes that the Government makes without any regard for the manufacturer, making them retroactive and as frequently as it pleases, Mr. Drefs' subject is becoming more and more vital. While it is to be hoped that there will be a lessening of such interference, it is much to be feared that it will have more permanency than we like to anticipate. If the careful thought of this and other societies can evolve some general methods along which improvement can proceed, it would be an excellent and beneficial thing to all industry.

JOHN MCGEORGE:—Mr. Drefs mentioned one subject that is very important, and that is where the burden should be placed. It was a new thought to me to lay the burden on the productive hours and not on the wages. In work by the day, they are one and the same; but when we consider piecework they are not. The most important point is to lay the burden in the proper place. We have heard and seen a great deal of the burden being put on the whole shop-cost, including materials. Is that correct? It is usually based on the productive wages. Is that correct? Mr. Drefs speaks of laying it on productive hours. Is that correct? Another point he raised which will bear very grave discussion, is the question of anticipated burden; that of determining the burden at least one month in advance. I know many places that take an average of the year for the burden, and it seems to me grossly incorrect to do that. I once kept the costs myself, in an establishment of which I was general manager; I determined them month by month, taking the previous month's burden for the current month. My costs ran very regularly and worked out very satisfactorily. I can see the point Mr. Drefs makes, that it should be anticipated and not following.

A. G. DREFS:—Overhead expense is very generally misunderstood and misapplied. The only way one can be sure of taking care of every dollar and cent of overhead expense is to tie it up with the general books by opening an account on the books called "manufacturing expense," and then crediting that account each month with what we call the "earned expense." In other words, after the expense is departmentized and we have 10 or 15 productive departments in the plant, a department might have an overhead expense of 75 cents per hr. Taking the actual hours in that department during the month and multiplying by 75 cents gives the earned burden for that month. Then by taking all of the productive departments and getting the total earned burden, we credit the controlling account in the general ledger and find the amount by which we were too high or too low. The balance will mean that we have been too low in the overhead rate if it is a debit balance; whereas, a credit balance will mean that the overhead rate we have used in the costs has been too high.

Returning to the point raised regarding the best method, we should first departmentize the costs and

get the contributing departments, such as the machine shop, separated from what we call the productive or manufacturing departments. Each department, of course, stands alone and we collect the charges in every department for non-productive labor, for taxes, insurance and depreciation, as well as the supplies used, through a requisition system. Then we take the contributing departments and levy them against the productive departments on a basis that will equitably reflect the usage of the productive departments of the contributing departments' facilities. In the case of heat, light and power, they are in relation to consumption. In the case of mechanical repair departments, it is in relation to the volume of repair work being done. After we have the expense in the direct productive departments, which includes the absorption of all the contributing departments' expense as well as their own expense items, then it sems to be that the most equitable way is to establish the expense burden in relation to the productive hours. With a proper production system, the time element is very necessary to schedule the work through the shop; hence the production and the costs tie-up, and thus I think we produce a fairer and more equitable expense basis and one that can be operated with a minimum of detail and red tape.

R. R. POTTER:—Has Mr. Drefs ever come in contact with the idea of distributing overhead expense on the basis of the equipment investment in the different departments? I have thought of that plan, although I have never tried it out or known of its being tried. As a matter of fact, the distribution of expenses on the basis of direct labor payroll is so much easier and simpler than any other way that it is probably used more than any other plan. We always know what our direct labor payroll is, and it is easy to apportion the expense on the basis of the direct labor payroll. It seems to me, however, that it is almost equally easy to ascertain the investment in machine tools and other equipment in each individual department, and then all fixed charges, provided the floor-space of the building were included in this investment, would be proportional to this investment. Many of the items of general expense, the machinery repair charges, for instance, would also vary closely with the amount of the equipment and building investment for each department.

MR. DREFS:—In my opinion, the distribution of expense on an investment basis would be very fallacious. The only item of overhead expense that is reflected on an equipment basis would be the item of depreciation; that, of course, is departmentized anyhow and shows against the particular department. In other words, if this were a milling-machine department, we would get the investment value of those machines and take a depreciation rate of 10 to 15 per cent, whatever was determined. In that way we would allocate against the milling-machine department its proper depreciation. In like manner, through a departmental basis, we would get the power charge against the milling-machine department by constantly checking up the power load. The lubricating oil, smaller tools and belts would be secured through a requisition system; in that way we would allocate against the milling-machine department all the items of expense by a method that would reflect their exact charge and exact consumption. The mere fact that we have milling machines costing several thousands of dollars apiece in one department and some small drill-presses costing only a few hundred dollars apiece in another department, does not mean that any expense other than depreciation should be distributed on the investment basis. Actually, there is no relationship at all and, while it would be an easy method, the investment basis does not apply. We must dissect the expense into its component items, charge them to a department and then apportion them on some equitable basis which, I believe, is the productive hour; or, where one operator operates several machines, the machine hour.

MR. POTTER:—I do not altogether agree with Mr. Drefs, although I am very appreciative of his reply. I think that in the case of the larger machines, for example, the repair charges and other expense items would have a considerable bearing and vary in some proportion to the machinery investment as compared with the small drill-presses. Another thing that charging on the production-hour basis does not take care of is machinery standing idle. If we charge overhead expense only on the basis of the hours in which the machines are producing and half of the machines in a given department stand idle, we naturally have a large amount of overhead expense which we should have distributed to that department which goes somewhere else. It is spread over the machines that are running and they have to carry the whole burden. Mr. Drefs mentions depreciation as the only item that could be distributed on the basis of equipment investment. After further thought, I am sure he would include interest, taxes, heat, maintenance and repairs, and perhaps mechanical supervision.

Mr. Drefs presented in his paper a number of principal features that a production system should contain. This seems to be in general and to apply to any production control system. I will ask Mr. Drefs whether he considers that it would be possible to establish S.A.E. standards for the principal forms for taking care of these chief features. I appreciate the difficulties that might enter such a plan and that no hard-and-fast forms could be outlined, but I believe it might be an interesting subject to discuss.

MR. DREFS:—I believe that a cost or a production system should be designed to meet the specific needs of a given problem. As I think I said, too many institutions have a system which is used just because some competitor had one like it. The thing to do is to study each individual plant, determine its personality or individuality and then design a cost or production system suited for that plant. That does not exclude standardization, because there are certain things that can be standardized. We can standardize the method of overhead distribution. While we cannot say that all departments should be the same, we can standardize on the method. We can standardize on the method of collecting labor costs and on the method of pricing materials. Some add to the cost of material the inward freight and handling charges; others charge the freight and handling to overhead expense. Items like that can be standardized and much can be done, although I believe that we cannot develop one system that would be suited to all plants, because there are too many individual factors in each plant which would cause difficulty in trying to install the same thing uniformly.

MR. MCGEORGE:—A very important question arises as to where the production department belongs. Is it a completely separate and independent department? Does the production manager belong in the engineering department? He must be an engineer; otherwise he cannot determine what machines the work shall be done on. If he requires special tools or special operations, who will plan those for him? Is he to take charge of that himself?

Is he to establish a separate drawing office, or is he to go into the general manager's department? Where is his place? Where should he be placed on an organization chart?

MR. DREFS:—As I see it, the four main functions in automotive institutions are financing, engineering, manufacturing and selling. When I speak of engineering, I mean designing and not plant engineering. In my division of manufacturing a production department would report direct to the general manager, just as the financing, engineering and sales departments would report direct to him.

A. J. LANGHAMMER:—Mr. Drefs spoke at length of production systems, particularly as applied to plants already established and producing. Possibly the greatest production problems arise when on a new project, such as the Liberty 12-cylinder engine, is started. On what basis should such a project be started? How would the production methods be applied when no records or working data are available? I believe that the Liberty engine manufacturing schedule was such that it was impossible to get correct costs. I think the final cost was at least 50 per cent greater than the original estimate made by the production men of the various engine-manufacturing companies.

MR. DREFS:—I am glad to answer that. Were I asked to devise a cost or production system for a new project like the Liberty engine my first procedure would be to try to get a bill of material. Then to take each part of that bill of material and, in conjunction with the man who designs the tools, secure each operation. I would then work out what I call my operation cards, getting my set-up time and my performance time, which would be an estimate at the start. Then, after those estimates had been procured, I would work out a templet similar to what I mentioned before, and lay it out for each part so as to get the correct starting time of each part on that Liberty engine. Ultimately, as we start to correct and improve the manufacturing conditions, the data would obviously be changed. I emphasized the fact that a good production system must have methods established whereby there is a constant corrective process. We cannot start out and be originally 100 per cent accurate; the scheme must provide means whereby new data, as they are developed, will flow to a central point and then be utilized for all future operations. I believe that the cost of a Liberty engine could have been better determined, leaving aside entirely the question of engineering changes that took place, if each part had been studied in the way I suggest. By taking each item, such as the pistons, and from their purchase cost, including the inward freight and handling charges, secure their total material cost. Labor and overhead costs would be secured by determining that they would be processed in a certain number of operations and that the operations would be on certain machines requiring certain tools. It is really surprising how accurately we can anticipate the costs. I think that very satisfactory results can be secured if each factor is properly considered.

During the war I was in charge of the administrative branch of the Motors and Vehicles Division. We made the Class B military trucks. Obviously, we ran into many mismade estimates and costs, but by making the original contractors detail their costs, there were very few of them from whom we collected profits over the guaranteed maximum of 15 per cent, or to whom we gave additional compensation due to the fact that they had made less than the guaranteed 5 per cent. It seems to me that much of that was brought about by the fact that we made the contractors detail each part, showing us the material, the productive labor and the overhead expense cost on it. By going through that detailed procedure the estimates were, I think, kept more accurately than they would have been otherwise and than they are ordinarily kept.

W. E. WILLIAMS:—The man who does not keep account of costs considerably in advance of when they actually take place will have much trouble; we should adopt a system that will allow the costs to be anticipated. The bane of my engineering experience has been that question of what the cost will be, not what the cost has been, for that money is already spent.

CHAIRMAN EMMONDS:—If at some time the Society could have a Liberty engine session, we could then discuss the good features that developed from the Liberty engine design and production. It was unlike anything that was ever done before. There is much in it that would be of benefit to everyone if the true history of just how and why each thing was done could be fairly and properly presented. An exact statement has never been published. Statements have been prepared, but conditions have never permitted their publication.

THE HUMAN ELEMENT IN PRODUCTION

BY A. F. KNOBLOCH

THE human element in industry and production is the one fundamentally essential element; all other elements are supplemental in their relation. Modern machinery supplements the human element; it does not supplant it. The human element was never more prominent than at present. Notwithstanding this fact, it is true that the human element in industry has had less constructive consideration at the hands of the American manufacturer and business man than other elements that enter into any given product. The American workman has been lifted out of the conditions under which he toiled formerly to a plane of life where he and his family secure more of the necessities and comforts of life than he was able to secure formerly and from which he will never recede to his former position. Those who use the human element in industry must recognize this and plan accordingly.

The need of increased production and the idea that production must exceed consumption are then discussed at some length and a detailed description of how one plant solved the labor problem is then given. [Printed in full in the August, 1920, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN HAROLD EMMONDS:—I call that an extraordinary and very interesting paper. It is especially interesting here because so many manufacturers are pessimists on the labor subject. It is delightful to know that Mr. Knobloch and others are not pessimists on this subject, that they have attacked it with the idea of overcoming it and that they are succeeding. It is a very difficult problem to solve, especially at present.

C. M. MANLY:—A most interesting thing to me, in Mr. Knobloch's paper, is the point he brought out that we have had our standards of value all shot to pieces. I think this is one of the fundamental factors of our

whole trouble today. One of the most important elements in the present unrest is the fact that standards of what is fair and what is proper have been so obliterated that everyone has been at sea as to what he ought to get as compensation and what that would enable him to purchase. The vital thing that Mr. Knobloch has shown how to accomplish is the establishment of a standard of fair dealing which lies at the basis of a contented mind. If the workman can be induced to believe that he will really have a fair deal, we will obtain his cooperation. That is the element which the system Mr. Knobloch has devised has really and fundamentally put into the proposition. I am delighted to have heard this paper.

JAMES E. HALE:—Will Mr. Knobloch outline his views on welfare work as it is commonly understood in industry, particularly regarding whether the movement is progressing and how far it is advisable to carry it.

MR. KNOBLOCH:—That is only a matter of opinion. I attended the session of the Chamber of Commerce of the United States and was presented at the meeting on production in which C. A. Eaton, of New York, one of the associate editors of *Leslie's Weekly*, spoke. Mr. Eaton said that two things are necessary to realize what both the employer and the employe want most; they are leadership and education, leadership primarily by the employer for the worker. Many of us have been delegating that leadership to the professional labor leader. It belongs naturally to the management of the plant and not outside of it. Only when the management proves its ability to lead labor has it a claim to eliminate the union, and this includes that peculiar relation which we in this country have termed welfare work. Much that does not belong to the work known as welfare work has accumulated under the term and has been used. In fact, we set up in many of our plants a professional duty of welfare which has frequently killed, and I am almost sure should kill, professional welfare service.

The American workman, I think, wants nothing that savors of charity, but he does want that which he has a right to expect under the leadership of his employer. This includes a human interest in this human element in industry which existed in the small shops where the employer and the employe lived side-by-side at the bench. The employer knew what the conditions were in the home of his employe, and he acted accordingly. He attended the christenings of the babies and the funerals in the family and saw to it that the employe was made comfortable. The turnover of labor was slight. Only to the extent that we can transpose into our corporate organizations that principle of human relation between the employer and the employe, do we really render welfare service.

H. W. SLAUSON:—Mr. Knobloch has shown us that the men in his organization, after they were convinced of the benefit to them of his system, accepted it wholeheartedly; but many of us have heard so frequently that organized labor is opposed to anything savoring of piecework and that the weakest man from the production standpoint shall represent the maximum of production. Will Mr. Knobloch state the approximate number of men in his plant affected by this system and also whether he has encountered any particular difficulty in introducing the time-study plan? We have read of many strikes that have occurred because of the presence of men with stop-watches. The workman cannot be brought to realize, in many instances, that stop-watches will react to his own benefit. I desire some information as to what might be called the selling methods used to convince the workmen that the time-study is undertaken for their eventual benefit.

MR. KNOBLOCH:—After the men once see the benefit of the square deal and get the opportunity to share in what they produce, they go to it. They are suspicious at first. It was my business to drag a dinner-pail to work when I was thirteen years old. I worked at piecework. I have seen the piece-work cut because we were making a showing and I have seen it cut repeatedly. I know what the results are. Until we have lived a generation of square dealing on a human basis with the American workman, we have no right to criticize his skepticism. To those who are interested in costs and management, the curve of the cost of the unit is absolutely flat. That has been one of the astonishing results. My board of directors has checked this up with the accounting department, and the accounting department has underwritten it as being right.

A. J. LANGHAMMER:—It seems to me that Mr. Knobloch's system is based primarily on the production count, the number of parts that are produced. Is the output of each operator counted? Is the work inspected before the count is accepted? Does the manufacturer pay for spoiled work or rejected parts?

MR. KNOBLOCH:—We pay for spoiled work in the count until it becomes prominent. We expect no man to be superhuman and give us a 100 per cent product. We have a standard for each operation; that is carefully checked up. If in a very simple operation the spoiled work is 1.5 per cent, when the workman exceeds that we take it up with the foreman. We hold the foreman and the workman responsible for the spoiled work and not the inspector. The result has been very satisfactory, as the percentage of spoiled work indicates. Another very good check is the sales-department and service-department reports of the behavior of the product in the field.

MR. LANGHAMMER:—Who does the actual counting of the parts?

MR. KNOBLOCH:—The counting is done by employes of the treasurer's department. It is an absolute audit. The treasurer's department has charge of the accounting, the time-keeping, and the counting of the work finished by each operative on each operation each day.

INTERDEPARTMENT PRODUCTION CONTESTS

BY R. R. POTTER

THE interdepartment production contest has proved notably successful in stimulating what may be called the athletic spirit, or spirit of sporting competition, between producing departments. It is evident that great advantages will accrue from the simplest form of contest where one producing unit, such as a blast furnace, is pitted against another exactly similar unit. It is not so obvious that these advantages can be extended readily to practically any manufacturing organization. To make this possible, it is only necessary to establish a simple and definite basis for comparing the volume of output of one unit or department with another or to reduce the production of departments, working perhaps on widely differing components, to what may be termed a "common denominator." It has been found possible to establish such a basis, which is sound in theory and which has proved satisfactory by actual trial over a period of many months to the

competing foremen in an automobile transmission factory. The effect of such contests upon employes is then discussed at length and their value to the management is commented upon. The form of score-board designed for the interdepartment contest is illustrated and described, followed by a description of the contest records and computations. The results show the plan to be sound in principle and capable of very wide application to industry in general. Its strength lies in its strong appeal to the sporting instinct and pride of competition inherent in all men. [Printed in full in the September, 1920, issue of THE JOURNAL.]

THE DISCUSSION

CHAIRMAN HAROLD EMMONDS:—I hope that this production session of the Society will come to be a regular procedure in the future. I will offer a suggestion. I have had a rather curious experience along this line. The first 13 years of my business life I passed practising law. I then went into the manufacturing business as an executive in an automobile company and in several other allied associations of the industry. I was there until the war commenced, when I reported for duty in the service as a naval reserve officer, which I have been for a long time. First, I was given an assignment on the other side for active sea duty but, instead, I was finally given the job of managing the producing of all the aviation engines for the Army and Navy. This started out as a reasonable proposition, but it became much more complicated. The total number of aviation engines finally required of us was 101,993. The companies that we succeeded in getting into this business were 23 in number, and the wonderful organization of men that took hold of it made it the most extraordinary work and accomplished the most extraordinary records of production and delivery in the history of the industry. Over 30,000 aviation engines, during the 15 months preceding the armistice, were completed, accepted and delivered for service. They had a total of approximately 8,000,000 hp. That was a third of the entire number of aviation engines that were expected to be required during the war.

So, I have had some experience in watching production men operate. I am not one myself, but I have watched those that are in that work and, as a result, I have the utmost respect for the man who is a producer. His troubles are ours; his problems are ours; all of us must help him. He needs good lawyers and good engineers to help him; but, when we get right down to the essence of it, the man who is essential is the man who produces. The producer is the man for whom we are all working and whom we all ought to help. It is the business of all of us to find out how we can help him the most, to tell him not what he cannot do but what he can do and how he can do it, to study production and production problems and find out how we can help to increase production and make it better.

I sincerely trust that the Society will make the production session a regular occurrence in its meetings; it should be a permanent factor, and I believe that each year you will find it more and more interesting.

LAWS FOR AIR TRAVEL

ALTHOUGH man's conquest of the air has been practically achieved and the age of flying is indisputably here, aircraft having become successively and successfully machines for sport, implements of warfare and vehicles of commerce, this country, which was the pioneer in successful flying, has no vestige of a system of jurisprudence for the control and regulation of man's activity in this newly conquered element. In this respect we have lagged behind most of the European nations. Our legislators have been slower than those abroad to realize the great and growing importance of the subject and have given it only scant attention. While no European country has yet attempted to formulate a complete system of jurisprudence to govern air travel, most of them have made a beginning in that direction.

Great Britain has its Air Ministry—established three years before the war ended—of which Winston Churchill is the head as Secretary of State for War and Air, and for several years this department has licensed pilots, inspected machines and exercised control over aerial navigation in Britain, one of the regulations it enforces being that cross-country flights in airplanes must be at a height of 5000 ft. Recently, in England, a flier was fined $250 in police court for making several Immelman turns at a height of 500 to 600 ft. from the ground.

A new air-navigation bill is now pending in Parliament. This measure is an embodiment of the air navigation convention framed by the International Conference held at Paris in October, 1919. That convention was drawn up on the principle that complete territorial sovereignty should be exercised by each nation over the air space above its own domain. Among the provisions of the bill are clauses giving local authorities power to acquire land for the furtherance and regulation of civil aviation, and dealing with jurisdiction in the subject of crimes committed in the air.

In France, the regulation of flying is vested in a Secretary for Aeronautics and the existing national regulations are strictly enforced, but those laws are now considered inadequate.

All air travel in Germany is under supervision of the Governmental Department of Transportation. Belgium, Holland, Switzerland, Italy, Spain and the Scandinavian countries have air codes of their own, which are strictly enforced and normally make improbable at least the dangerous practices often indulged in in the United States.

In the 12 months preceding last July, within the British Isles alone almost 700,000 miles had been flown by airplanes of all types. More than 67,000 passengers had been carried and more than 100,000 lb. of freight transported. In that period there had been only four fatal accidents and 20 other minor accidents without fatality. Actually, 28,877 miles had been flown for every accident.

The United States is far ahead of the rest of the world in aerial mail service, but this is the only aeronautical undertaking in which we lead.

To make air travel safe, inviting and profitable, and to encourage commercial flying and the business of air transport, airplanes must be required to use "highways of the air" prescribed by the Federal Government and landing fields and airdromes owned or licensed by the nation and controlled and operated under rules and regulations based on an international code administered by officers of the Federal Government in a manner somewhat similar perhaps to that regulating steam vessels used in navigable waters. And the inspection, licensing, designating and numbering of aircraft, the licensing of pilots, and the like, should be uniform for the whole country.

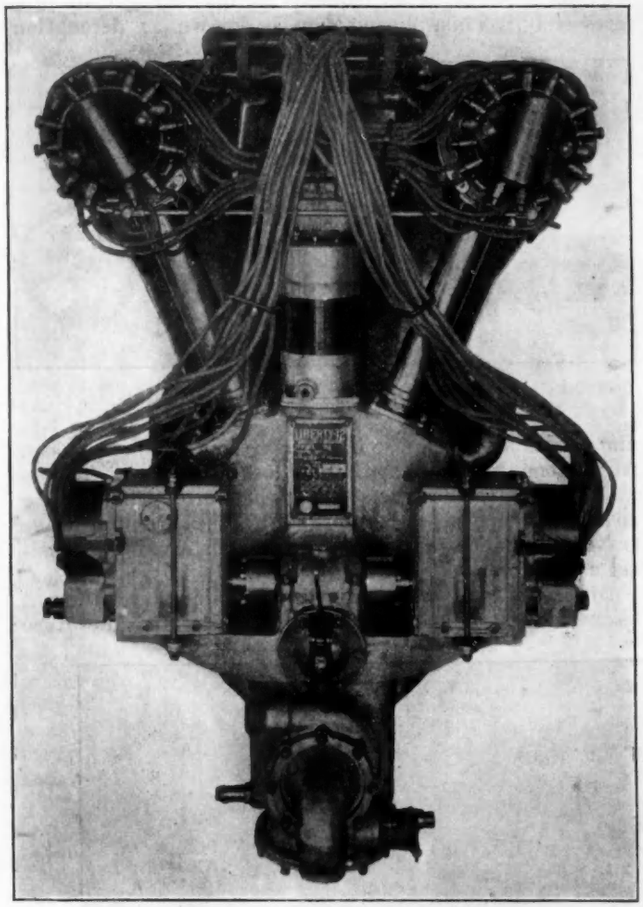
From the very nature of the possibilities of air travel and transport, the whole subject of aerial legislation must be based upon an international convention, have international concurrence and bring eventually great and radical changes in the laws pertaining to communications, transportation and commerce.—G. W. Harris, in *N. Y. Evening Post.*

Ignition from the Engineman's Viewpoint

By Capt. George E. A. Hallett,[1] U. S. A.

Metropolitan Section Paper *Illustrated with* Photographs and Chart

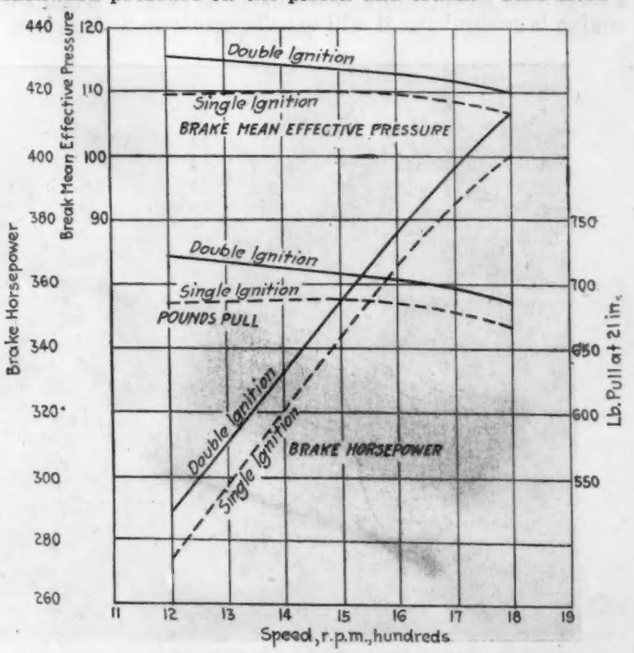
It is intended to discuss ignition in this paper in a broad and non-technical way. The definition of the word ignition should be broad enough to include the complete functioning of the ignition apparatus, beginning from the point where mechanical energy is absorbed to



Liberty Engine Equipped with Two Ignition Systems

generate current and ending with the completion of the working stroke of the engine. The ignition system includes the mechanical drive to the magneto or generator and the task imposed on the system is by no means completed when a spark has passed over the gap of the spark-plug. Ignition means the complete burning of the charge of gas in the cylinder at top dead-center, at the time the working stroke of the piston commences. The means employed to accomplish this result is the ignition system. In the present-day type of gasoline engine a spark produced by high-voltage electricity is almost universally used for ignition. This high-voltage electricity is produced by an electrical transformer. The transformer "steps up" the lower voltage produced from the source of current, which may be permanent magnets or a storage battery. Regardless of the source, the result must be efficient ignition if maximum power output per gallon of fuel is to be obtained.

To grasp the idea of what takes place in an internal-combustion engine cylinder, let us think of the whole program of events slowed down for the sake of convenience. Picture the combustion-chamber full of compressed mixture or gas, then a spark occurring between the spark-plug points. A small flame is then started by the spark and spreads out radially from the spark-plug, somewhat as ripples spread out when a stone is thrown into a pond; but this flame, unlike the ripples, proceeds at a constantly increasing rate of speed. We speak of the speed at which the flame travels through the charge as the rate of flame propagation. Finally, the entire charge is ignited and this should end the program. This stage of the combustion should be reached by the time the piston is ready to start down the working stroke. All this program requires considerable time, therefore, in order that it may be completed by the time the piston starts down, it is very necessary to start the program by causing the spark long before the crank and piston reach top center. This is called advancing the spark. The result is that, during the first phase of the ignition, pressure is building up rapidly in the cylinder and causing a reverse torque or backward pressure on the piston and crank. This is ob-



Test Results of the Single and Double Ignition Systems on a Liberty Engine

[1]M. S. A. E.—Chief of powerplant section, engineering division, Air Service, Dayton, Ohio.

viously even worse than wasting power. To reduce the amount of spark-advance needed we must arrange to burn the charge of gas much more rapidly. There are three principal ways to make the charge burn faster:

(1) If we can light the gas on all sides and in the center simultaneously, it will cause the charge to burn more rapidly, just as when, in burning a pile of brush, it burns faster if the torch is applied on all sides instead of at one point only. This is an argument for using more than one spark-plug per cylinder

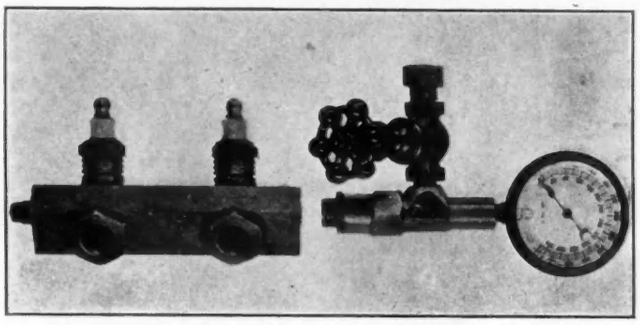
(2) If the spark continued through a much longer period and the gas could be agitated within the cylinder or rotated fast enough so that most of it passed the spark while the crank moved only a few degrees, we would have much the same effect as if the spark-plug ran around the edge of the cylinder, igniting the gas on all sides almost simultaneously. This is an argument for turbulence

(3) The use of high compression pressures will cause the flame to travel through the charge much faster and will at the same time give us smaller combustion-chambers. This means that the flame will not be required to travel so far, and will also give several other advantages which will not be mentioned. The objection to using high compression is that it causes knocking or a detonation and frequently preignition

Preignition and Detonation

Whenever, for any reason, some part of the cylinder such as a valve, spark-plug points or flakes of carbon become sufficiently hot, they will ignite the charge. Such ignition generally takes place much too early and long before the spark would occur. This is called preignition. Frequently preignition causes a flame to remain in the cylinder through the entire four strokes of the cycle, and generally causes a great drop in power. We have learned recently that hot valves seldom cause preignition, while hot spark-plug points frequently do cause it. When the compression of an engine is raised, the temperature of both the compression and the expansion strokes is raised. Preignition is, therefore, more likely to occur. When an engine is preigniting it will usually continue to fire more or less regularly for a moment after the ignition is cut off. Preignition must not be confused with detonation and knocking. They are two entirely different phenomena. Either one can lead to the other, but they seldom occur at the same time.

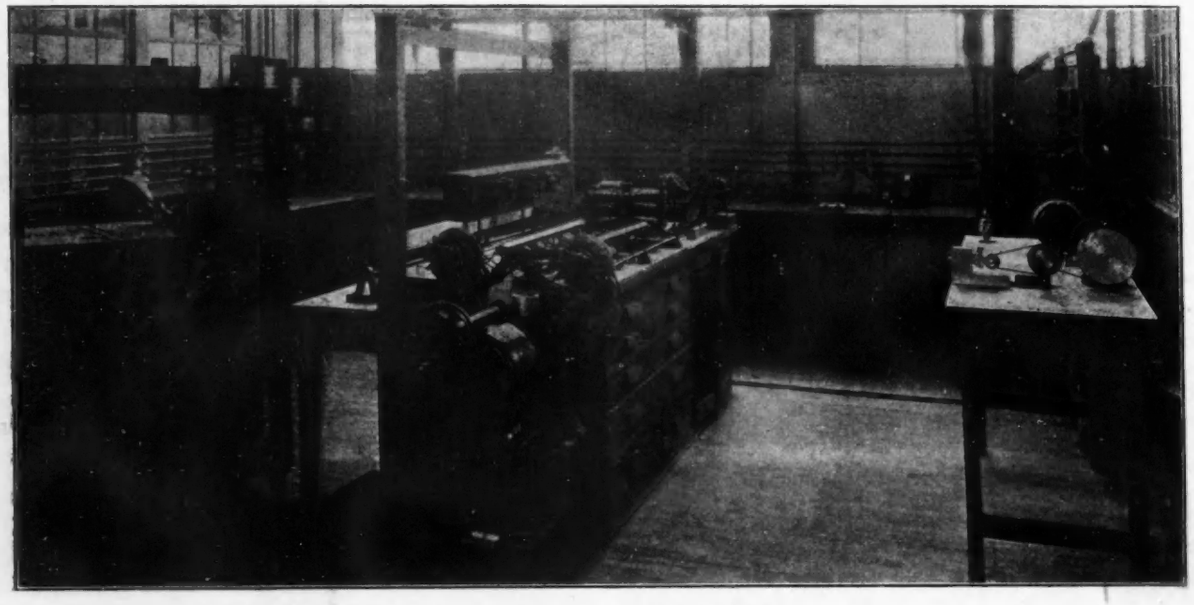
As mentioned earlier, the spread of the flame through the charge is progressive when an engine is running normally, but this is not the case when an engine is knocking. We have all driven a car up a hill in high gear when the engine is full of carbon and have encountered loud knocking or "pinking" in the engine. This we have lately begun to call detonating. When an engine is detonating the flame starts out from the spark-plug and passes through the charge progressively at first but, after it is for example half way through the charge, the portion remaining unburned has reached the critical temperature at which spontaneous combustion takes place and, as a result, it all explodes at once instead of progressively. This phenomenon is known as detonation



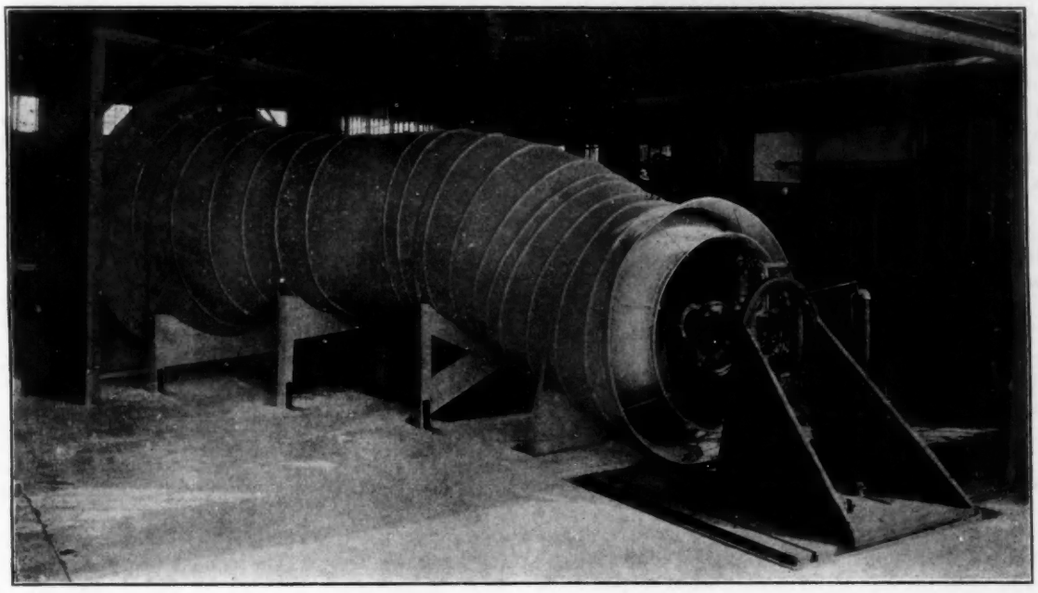
Spark-Plug Testing Device

and causes a sudden rise in pressure like a hammer-blow, which soon dies down again and does little work. This is an explosion in the true sense of the word. The pinking sound is believed to be caused by the pressure wave traveling faster than sound travels, thus causing a musical note.

Different fuels when mixed with air have different temperatures of spontaneous combustion and therefore



Liberty Engine Ignition Test Rig



SIDE VIEW OF THE AIR-COOLED TEST RIG

detonate under different conditions. Kerosene detonates more easily than gasoline. The compression used in automotive engines is easily limited by detonation.

TWO SPARK-PLUGS PER CYLINDER

If the charge is ignited at several suitable points simultaneously, only comparatively small bodies of unburned gas remain during the last phase of ignition and therefore higher compression can be used without encountering detonation. Or, the detonations may be so small that they are not noticeable and cause no trouble. I saw recently a four-cylinder L-head truck engine pulling a load at 500 r.p.m and knocking badly. By throwing a switch, sparks were caused in additional spark-plugs in each cylinder. All signs of knocking or detonating instantly disappeared, and the engine ran very smoothly.

One bad condition which causes detonation is when a hot exhaust valve is in one side of the cylinder and one or more spark-plugs are in the opposite side. In this case the last portion of the charge to be ignited is being pre-heated by the hot-valve, so that it reaches the detonation temperature earlier than it otherwise would, thus causing excessive knocking. I talked recently with a man who has a car equipped with a T-head Benz engine and asked him to cut out the ignition on one side of the engine and then on the other alternately, to observe which spark location gave the most knocking. The experiment showed clearly that this engine knocked badly when the spark-plugs over the intake valve were used. In that case we had the hot exhaust valve helping to heat the last portion of the charge which was burned. This engine knocked only slightly when the plugs over the exhaust valves were used and, when both plugs were used, the driver noticed much smoother running and some gain in power.

DOPED FUEL

Mr. Kettering and Mr. Midgley have developed certain compounds at Dayton which, when put into gasoline or kerosene, raise the critical temperature of the fuel or the temperature at which detonation takes place. Such "dopes" are entirely practical to use and make practical the use of far higher compression in automotive engines, thus greatly increasing mileage and power output. When doped fuel is used, carbon becomes an asset instead of a liability because the carbon forms a partial insulation which reduces the amount of heat wasted into the water-jacket; and at the same time decreases the volume of the combustion-chamber and in this way raises the compression pressure.

At McCook Field, we recently tested a 5½ x 6½-in. cylinder with about 118 lb. per sq. in. compression, or a compression ratio of 5.4 to 1, and noted a gain in power in the use of four spark-plugs over one and also in the use of four over two spark-plugs. The gain when using four spark-plugs was about 11.1 per cent, and in the second case about 5.7 per cent.

POWER RESULTS WITH FROM ONE TO FOUR SPARK-PLUGS

Spark-plug Location	Speed, r.p.m.	Brake Load, hp.	Actual Brake Horsepower	Brake Horsepower Corrected to 29.92 in. of Mercury	Theoretical Brake Horsepower
One under intake valves, one under exhaust valves ..	1,800	85.5	38.5	40.0	44.1
One under intake valves	1,800	81.0	36.5	37.9	41.8
Two under intake valves	1,800	85.5	38.5	40.0	44.1
Two under intake valves, one under exhaust valves ..	1,800	88.5	39.8	41.4	45.6
Four plugs firing...	1,800	90.0	40.5	42.1	46.4

Throttle and speed constant; spark and load variable; barometer: 28.79 in. of mercury.

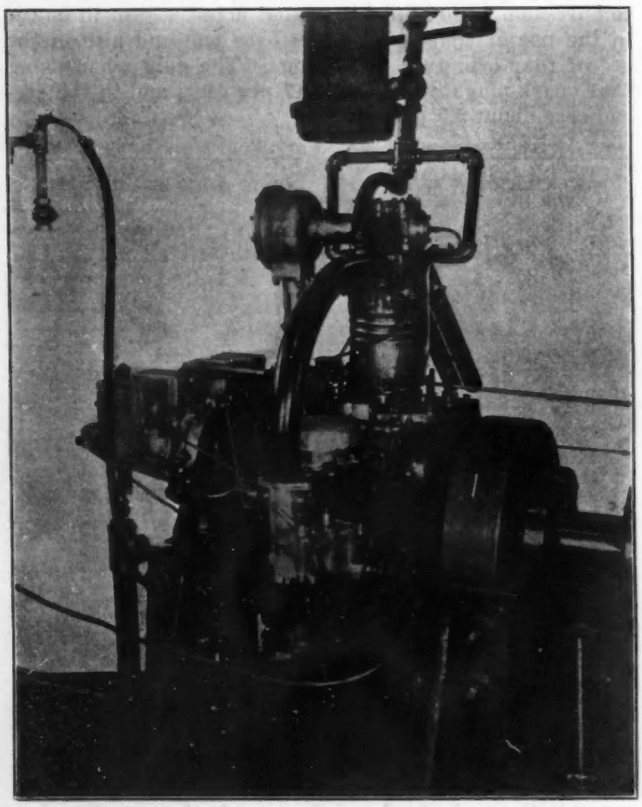
The accompanying table shows the results. The first column is the speed at which the engine was run, the second is the brake load and the next is the actual brake-horsepower. The column next to the last is the only one

we need interest ourselves in; it gives the corrected brake-horsepower. The number and arrangement of spark-plugs is shown at the left. The second line shows the minimum power, which is with one spark-plug under the intake valves. The third line shows two spark-plugs under the intake valves and shows some increase in power. The bottom line shows four spark-plugs firing and shows the highest power. These tests were made with due regard for the best spark-advance for each combination, and using various spark-plug locations.

The universal test machine on which the cylinder in question was tested is shown. It is a 5½ by 6½-in. four-valve cylinder, designed for use on an 18-cylinder engine. This engine is arranged to test almost any kind of cylinder, either air or water-cooled. The compression is varied by raising the cylinder up or down, and we have also arranged one cylinder on which we can change the valve-timing while running, for experimental purposes. At present we are doing much interesting work in the development of air-cooled cylinders on these universal test engines.

In preparing an engine for use in the Gordon-Bennett race, we changed the compression from 118 to about 160 lb. per, sq. in., used an especially prepared or doped fuel, and increased the power of the engine more than 11½ per cent. The economy was also increased to a very great extent. I feel that, when such gain in power and economy is available by the use of high-compression and doped fuels, there can be very little doubt that these things will be used.

As most of the tests were made at constant speed, the amount of fuel drawn into the engine was the same in each case; therefore the specific fuel consumption was materially reduced by the use of multi spark-plugs. Also,



A Cylinder with Four Spark-Plugs Mounted on a Universal Testing Engine

it was very noticeable that the use of four spark-plugs eliminated the tendency in this particular cylinder to pink or detonate. I am convinced that even small automobile engines will benefit by the use of two spark-plugs per cylinder if they are properly located, because this would probably permit the use of slightly-higher compression, the ignition by one spark-plug would tend to burn the other one clean in case of fouling, and there would be less tendency to knock. So-called "strong" sparks, or well-synchronized multi-sparks, show a tendency to keep the exhaust valves cooler. This is due to lower exhaust temperatures caused by more rapid and complete combustion during the working stroke. The choice of number and location of plugs is an engine-development problem, but the ignition engineers must make good multi-spark apparatus available.

The advent of lower-grade fuels for automotive equipment has tended to make ignition uncertain, with the present ignition devices and spark characteristics. Higher compressions make ignition more certain, but present difficulties due to higher resistance at the spark-plug gap. The tendency toward the use of higher compressions is very marked and I venture to predict we will have compression as high as 160 lb. per sq. in., used in conjunction with special or "doped" fuels, in the near future.

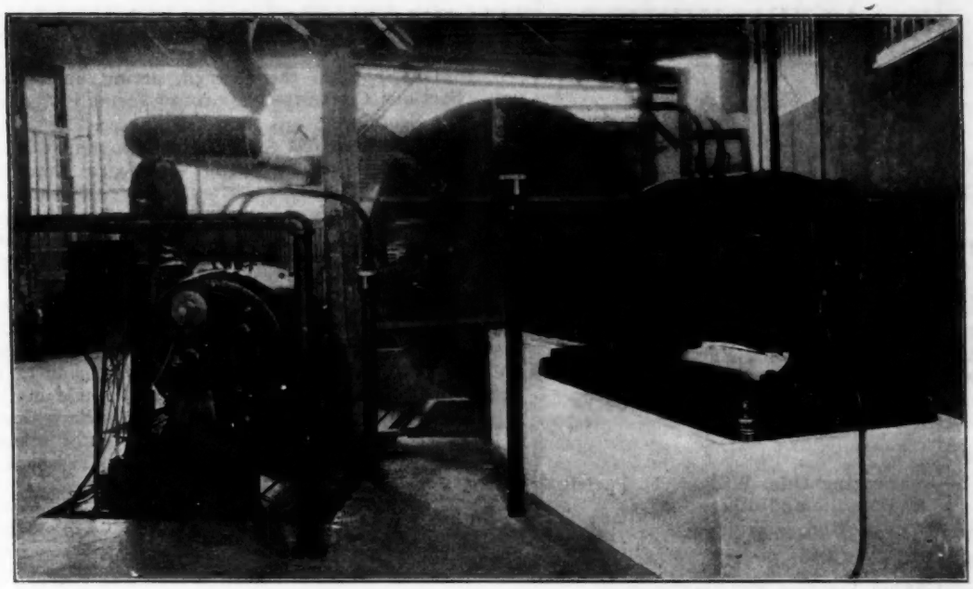
Certain and Uncertain Ignition

In speaking of ignition being certain or uncertain, it is meant that the use of low-grade fuel tends to make the conditions occurring in the cylinder immediately after the passage of the electric spark between the spark-plug terminals uncertain as to the rapidity of flame propagation or completeness of combustion. When higher compressions are used, if the charge is ignited at all, it burns much better. Ignition conditions really do contribute to good or bad flame propagation and combustion in engine cylinders. For example, some kinds of ignition sparks frequently called "weak" may be tardy in igniting the charge. This usually results in irregular combustion or slow burning of the charge, and uneven impulses in the engine. Sometimes the good effect of a more suitable ignition spark is offset by bad spark-plug location or unsuitable spark-plug length. These conditions can cause much the same result as a so-called weak spark. A good spark, well located, tends to give prompt quick ignition with more complete combustion. It is believed that the use of stronger sparks, or multi-sparks properly synchronized, can improve greatly the results obtained from the present types of engine. Of course, if multi spark-plugs are used and the sparks are not properly synchronized, the results are apt to be the same as from one spark-plug.

To explain further, we only have to carry this idea to a ridiculous extreme. Suppose we provide two spark-plugs and the spark occurs in one at the proper time and 40 deg. later in the other. Obviously, the one occurring late is too late to do any good in helping to increase the rate of flame propagation; therefore the results are the same as with one spark-plug.

Spark-Plug Tests

At McCook Field we necessarily test a great many makes of spark-plugs and, because a very small percentage of these plugs will stand up in airplane engines, we arrange the test so that the poorest plugs are eliminated with the least expense. Our first test is a short one, in a single-cylinder Liberty engine. Most plugs either break or show serious preignition in this test, but those that



END VIEW OF THE AIR-COOLED TEST RIG

pass this test are then placed in a multi-cylinder engine on a dynamometer, where the tendency to preignite and heat breakage can be noted. After this they are tested in the same engine on a torque stand, where they get the cooling effect of a propeller blast. During this test an attempt to foul the spark-plugs is made. This test is also a check on their durability, to make certain that they will last long enough to make a flight safely. For this torque-stand test they are placed in an engine installed in an airplane. This airplane is then flown up to a 10,000-ft. altitude and dived down to a low altitude repeatedly, to further test the liability of the plugs to foul. When all of the foregoing tests have been completed, the plugs are used in regular flights until a 100-hr. endurance record has been made. Thus far, only about three American makes of plug have passed these tests and are good enough for service.

We are now experimenting with the Midgley indicator for accurately determining the presence of preignition. We find that preignition frequently burns off spark-plug electrodes in high-compression engines, but it is interesting to note that the use of dope in the fuel eliminates this trouble.

Recently I put a standard Liberty engine on a torque stand, to run with ordinary automobile gasoline, to ascertain how much trouble would be encountered. The first trouble was this burning-off of spark-plug electrodes. Incidentally, we found that the pistons were cracked, due to preignition; but, when we used dope in this same fuel, we obtained almost the same power we would get with high-test gasoline and no longer burned off the electrodes.

Spark-plugs should be made to withstand even higher compression without causing preignition from now on. Preignition is now conceded to be equally as serious a condition as fouling, if not more so. Almost all automobile spark-plugs will preignite in an engine with a compression of 118 lb. per sq. in. I believe, therefore, that spark-plug designers will have to do considerable development work. Perhaps much smaller spark-plugs would cool better than the present standard size, and perhaps plugs can be made which will contain no cavity to hold gas and cause preignition by over-heating it.

A spark-plug was submitted to us for test late last year, in which there was no cavity for the gas to enter. The plug might be pictured as having merely a round knob on the end which, if polished with sand-paper, would show a narrow strip of mica around the side of the domed end. The spark was supposed to jump across this strip of mica. These plugs were hand-made by a farmer down in Arkansas and were of such poor material that they would not stand up, but I considered the type interesting because it was entirely closed. I believe that the electrode could be run hotter without causing preignition.

MECHANICAL DEFECTS IN IGNITION SYSTEMS

We now have many automotive engines developed to a point where stoppages due to failures in the basic engines are exceedingly rare. Most stoppages are due to clogging of the gasoline feed, or to ignition troubles. There was a time when we had many troubles such as valves sticking or warping and burning out, piston-rings breaking, etc., but most of these have been eliminated. We would now like to see the same thing accomplished in ignition apparatus.

I know of no case in which ignition engineers have gone to extremes in the strength of the spark and therefore I do not see how the present limitations of spark strength, duration, etc., were reached. It occurs to me, for example, that it might now pay to make ignition apparatus so that it delivered sparks perhaps three times as hot as those now in use and to design spark-plug points to withstand this high tension. It might thus be possible to keep spark-plugs clean when the engine is idling, due solely to the heat of the spark. Also, it might pay to let the spark continue through perhaps 40 or 50 deg. of crank travel, so that it could ignite any unburned gas that might sweep by the plugs during the burning of the charge.

We are approaching the point where ignition apparatus is cramping engine design. The voltage and other characteristics of present sparks are becoming part of the limiting factors in the compression pressures and, therefore, in power and economy. Also, ignition apparatus is helping to limit the cheapness of fuels which we can use and still be able to start engines and run them under idling conditions.

ACTIVITIES OF THE SECTIONS

Sections Calendar

Buffalo
Nov. 30
Jan. 11

Detroit
Nov. 19—Banquet
Dec. 17

Metropolitan
Nov. 11—Barbecue
Dec. 14—Tour of Yacht and Engine Plant.
Jan. 20—"Service," by Cyrus J. Rankin
Visit to large New York Service Station

Mid-West
Nov. 12—Lubricating Oils, William F. Parish, A. Danville and others
Dec. 3—H. E. Morton

Minneapolis
Nov. 3—Garden Tractors and Implements
Dec. 1—Present Status of the Tractor Industry
Jan. 5—Future Outlook for the Tractor
Feb. 2—Fuels
March 2—Good Roads and Equipment
April 6—Tractor Service and Repair Equipment

MEMBERS of the Society who are located in New England will be particularly interested to learn of the successful formation of the Boston Section. This is the first of a number of proposed new Sections to actually begin operations. Over 30 members of the Society met at a dinner held at the Engineers' Club in Boston on Sept. 22 to discuss the advisability of having a local organization. James F. Cavanagh acted as toastmaster and called upon a number of members to express their views. There was no one of the group who was not thoroughly convinced of the desirability of such an organization and several men expressed themselves as having seriously felt the lack of a common meeting ground for those interested in automotive lines.

R. E. Northway, who was largely responsible for the success of the dinner, was elected temporary chairman. Additional temporary officers named were James A. Moyer, vice-chairman; H. E. Morton, secretary, and E. Southworth Church, treasurer. The standard Section Constitution, By-Laws and Rules were adopted, and a petition was addressed to the Council and signed by all of the members present asking that the Section be formally recognized. Committees on Meetings and Papers and on Nominations for permanent officers were selected.

The success of the Section seems assured. Before the close of the initial gathering the Meetings Committee announced that a dinner followed by a technical session on Oct. 20 at the City Club had been arranged for, and the Treasurer reported that 27 prepaid applications for Section membership had been received. Members of the Society desiring to join the Boston Section should communicate with H. E. Morton, B. F. Sturtevant Co., Hyde Park, Boston.

On Sept. 25 the Council, acting upon the advice of the Sections Committee, approved formally the establishment of the Section.

It has been felt for some time that members of the Society who reside on the Pacific Coast are somewhat handicapped through inability to attend many of the meetings of the Society or of the existing Sections. Approximately 100 members live in or near San Francisco or Los Angeles and it is believed that informal organizations operating along Section lines there could do much to bring these members into closer contact and provide opportunity for the presentation of engineering papers on such subjects as may be of general and local interest. The Council has therefore appropriated $500 for use this season in defraying in part the expenses incident to meetings to be held in Los Angeles and San Francisco. There is reason to believe that if these meetings accomplish what it is confidently expected they will, regularly organized sections will be in operation in both of the cities at a relatively early date.

Current Meetings

The Metropolitan Section members listened on Oct. 14 to a paper by Charles Froesch on the Present Status of Isolated Gas-Electric Generating Plants. Mr. Froesch exhibited at the meeting a typical example of the apparatus under discussion. An added feature of the evening was an interesting talk by Ethelbert Favary on Present European Conditions. Mr. Favary had just returned from a trip through France, Italy, Germany, Rumania and Czecho-Slovakia.

The Mid-West Section meeting on automotive engine fuel matters, which was to have been held on Oct. 8, was postponed to Oct. 15. Thomas Midgley, Jr., opened the discussion, being followed by several members qualified to speak on the subject.

The Pennsylvania Section held its first meeting of the present season on Oct. 20. E. W. Templin spoke on The Future of Highway Transportation as It Affects the Automotive Engineer.

Other Section meetings held during October were those at Buffalo on the 19th, Boston on the 20th and Detroit on the 29th.

The Metropolitan Section has announced a barbecue to be given on Nov. 11. Additional meetings scheduled by this Section include one on Dec. 14, which will include as a feature an inspection of a yacht and engine plant, and one on Jan. 20 at which the subject of Service will be treated by Cyrus J. Rankin. In connection with the latter session the Section will visit a typical large New York service station.

The Mid-West Section has scheduled for Nov. 12 a session for lubrication. William F. Parish will present a paper on Engine Lubrication. Chassis lubrication also will be discussed. Upper cylinder lubrication will be treated by A. Danville.

On Dec. 3 the Mid-West Section meeting speaker will be H. E. Morton. The subject will be announced later.

Other Section occasions that have been announced are a dinner by the Detroit Section on Nov. 19 and a meeting on Dec. 17. The Buffalo Section has arranged for meetings on Nov. 30 and Jan. 11.

The Minneapolis Section has arranged to hold its meetings on the first Wednesday of each month. In addition to papers on various phases of the tractor subject, the discussion of the ideal farm tractor will be continued throughout the year.

DATA ON THE DESIGN OF PLYWOOD FOR AIRCRAFT

REPORT No. 84, recently issued by the National Advisory Committee for Aeronautics, gives the results of investigations of plywood made by the Forest Products Laboratory of the United States Forest Service at Madison, Wis., for the War and Navy Departments. Sufficient discussion on the mechanical and physical properties of this material is included so that the data can be used intelligently. The data, although intended primarily for aircraft design, have a broader field of application in the field of body engineering, particularly. A copy of this report can be obtained upon request from the National Advisory Committee for Aeronautics, Washington.

Current Standardization Work

THE S.A.E. HANDBOOK, with which practically all of the members of the Society and many others are familiar, is a measure of the standardization work the Society has carried on for over 10 years. It is the result of a tremendous expenditure of time and energy by the large number of members of the Standards Committee in the development of the well known standards and recommended practices which have meant so much to the automotive industry. Experience gained from year to year has been reflected in the form of revisions or new standards. The present arrangement of the Handbook is essentially the same as has been used from the beginning except for the addition within recent years of the comprehensive index and the separate list of official standards and recommended practices. It has been thought for some time however that in order to arrange the data in the Handbook in such a way that they will be of the greatest assistance and value in the daily work of automotive engineers, a number of important changes should be made to correlate better many standards that are intimately connected and to rearrange the entire Handbook into well defined groups such as Powerplant, Materials, Electrical Equipment and Axle and Wheels. The Society announces that a new edition of Vol. I of the S.A.E. HANDBOOK, which will contain only the official S.A.E. Standards and Recommended Practices, is now in course of preparation and it is hoped will be ready for distribution to all members of the Society before the first of the year. All members of the Society will receive the new volume without cost when it is ready for distribution, to replace the one now in their possession. Vol. II of the Handbook, to be revised later, will contain general automotive engineering data.

Important subjects on which definite progress has been made recently or with regard to which Divisions of the Standards Committee are in correspondence with the industries, are indicated hereinbelow.

ELECTRIC TRANSPORTATION DIVISION

A Subdivision of this Division has been considering for some time standardization of storage batteries for industrial trucks and electric passenger and commercial vehicles. The preliminary report includes overall dimensions of the batteries for industrial trucks and tractors. For electric passenger and commercial vehicles the tentative report includes a classification of batteries into four groups, as well as specifications and dimensions for rubber jars. All of the reports of the Subdivision will be considered at the next meeting of the Electric Transportation Division.

MISCELLANEOUS DIVISION

The subject of spring shackle-bolts, which was originally before the Springs Division, is being referred to the industry for information relative to desirable standardization. This inquiry will go into considerable detail and it is hoped a sufficient number of replies will be received promptly to enable the Division to make a report at the Standards Committee meeting next January.

It was suggested some time ago that the present S. A. E. Standard for heavy and light lock washers should be revised, but the Miscellaneous Division felt that the present standard should be retained, in view of the statement of the Association of Lock Washer Manufacturers that the great majority of automotive lock washers are made to the present S. A. E. Standard. A Subdivision has been appointed however to obtain data as to lock-washer sizes used in present production which are lighter than the present standard light series, in order if necessary to consider an extension of the present standard to include such sizes.

A detailed Subdivision report on horn mountings has been submitted, giving information relative to present methods of installing signalling horns, a comparison of dimensions as between different makes and methods of mounting and a recommendation to be considered for presentation to the Standards Committee.

ELECTRICAL EQUIPMENT DIVISION

The Battery Subdivision of this Division has been working for some time in cooperation with the Motor Transport Corps and the Bureau of Standards in the formulation of specifications for starting and lighting batteries for use on military automobiles and trucks. It has taken a long time to obtain and review comprehensive data in this connection. Final specifications will probably be issued by the Motor Transport Corps or its successor in the near future. Although the Society has been active in this work, it is not contemplated that it will adopt any specification for purely military purposes as an S.A.E. Standard. In connection with the present S. A. E. lead storage battery standards careful consideration has been given revision and coordination into a single complete standard. The Subdivision has prepared a report to be considered by the Electrical Equipment Division at its next meeting, covering sizes and capacities, ratings, terminal posts and compartment sizes. It was not considered desirable to attempt any standardization of jar sizes for gasoline passenger cars and commercial vehicles as this would tend to limit development in battery design. Variation of jar sizes does not, of course, prevent interchangeability of batteries in motor vehicles.

The report made by the Insulated Cable Subdivision some time ago is now being revised.

The Electrical Equipment Division has expressed the opinion that the S. A. E. standard tapered shaft for large-type motorcycle magnetos is suitable for the small-type magnetos developed recently for installation on motorcycles and on isolated electric light plants.

ENGINE DIVISION

In connection wih the present standard disc and cone-clutch flywheel-housings, the Engine Division has recommended that the maximum bolt-circle of the crankshaft flange shall be 5 in. The purpose of this recommendation is to permit interchangeability of the various commercial makes of clutch in standard flywheel housings.

As the result of investigation by a Subdivision, the Division has recommended that

> The nominal diameter of the carbureter intake shall be the inside diameter and vary in even ¼ in., so as to take S. A. E. standard flexible metal tubing sizes. This applies also to the outlet of carbureter air-cleaners, heaters and similar devices wherever tubing is used.

After careful investigation of the possibility of standardizing mufflers, the Engine Division has recommended that

> Mufflers shall vary in diameter and length in even inches and shall be supported by bands extending around their circumference.

Development of the powerplant in automobiles has brought wider fan belts into use on trucks and tractors. The Division has accordingly recommended that the present standard be extended to be as follows:

Nominal Belt Width, in.	Nominal Pulley Width, in.
±1/32	±0.005
¾	0.875
1	1.125
1¼	1.375
1½	1.685
1¾	2.000
2	2.250

Transmission Division

A Subdivision is preparing a report on the standardization of universal-joint companion flanges, with the thought of reducing much trouble and expense now experienced because of lack of interchangeability.

One of the most important subjects before the Transmission Division is a standard for the transmission drive for speedometers. Much work must be done before a recommendation can be made that will be acceptable to the manufacturers of the equipment involved.

Lubricants Division

The personnel of the Lubricants Division is being extended to include representatives of petroleum, fuel and lubricant producers as well as members whose work lies in the field of research. It is intended that the Division shall study carefully lubrication problems with the purpose of preparing standard specifications for use in the automotive industries generally. The entire Division attended the meeting held at the Bureau of Mines in Washington on Oct. 18, when revision of the Government specifications for petroleum fuel and lubricants was considered.

Iron and Steel Division

Extension of the Notes on the Physical Properties of S. A. E. Steels to include representative steels in all the groups has been under consideration. The preparation of data in this connection involves a tremendous amount of work much of which has to be done in the testing laboratories. This is considered one of the most important subjects before the Iron and Steel Division.

A Subdivision is preparing specifications for steel sheets of the type used in the automotive industry. Considerable information must be secured from the industries in furtherance of this work.

The Steel Tubing Subdivision recommended tentatively the following changes in the present S. A. E. Standard:

(1) Change the title from Cold-Drawn Seamless Steel Tubes to Structural Seamless Steel Tubes, in order that all classes of automotive tubing, including that used for aeronautical structural purposes, shall be covered by the standard

(2) Add 3/16, ¼ and ⅜-in. diameters, the first two having 18 and 20 B.w.g. wall thicknesses, and the ⅜-in. diameter 16, 18 and 20 B.w.g. wall thicknesses; also 14 B.w.g. wall thicknesses for 1-in. and larger diameters, in order primarily to include tubing used largely by the motorcycle manufacturers

(3) For hot-rolled seamless tubing the variation in wall thickness shall be plus or minus 12½ per cent

(4) For cold-drawn seamless tubing the variation in wall thickness shall be plus or minus 10 per cent

(5) Welded steel tubing shall have a variation in wall thickness of plus or minus 0.005 in. This type of tubing is made of rolled sheets which can be manufactured within close limits before forming and welding

(6) "Ovality" variations on outside and inside diameters shall not be over ½ per cent but not less than 0.005 in.

The Subdivision is now considering the advisability of specifying hardness limits for various grades of tubing and acceptable methods of determining hardness, strength or other physical properties of various grades of commercial tubing.

Progress is being made in research work necessary prior to formulating specifications for cast-iron for valve-heads. Possible revision of the present S. A. E. standard round and impact steel test-specimens is contemplated. This subject is closely related to that of physical properties.

The complete report of the Iron and Steel Division, including the types and analyses of steels adopted by the Society to date, has been reprinted and is now available.

Schedule of Division Meetings

A schedule of the various Division meetings for the month of November follows.

DATE	DIVISION	PLACE
9	Industrial Truck and Tractor Subdivision	Cleveland
10	Ball and Roller Bearings	New York City
	Engine	Detroit
11	Radiator	Detroit
12	Roller Chain	New York City
	Transmission	Detroit
15	Iron and Steel	Detroit
16	Non-Ferrous Metal	Detroit
17	Electrical Equipment	Detroit
18	Electrical Equipment	Detroit
19	Miscellaneous	Detroit

ENGINEERING FOUNDATION

WITH an income of $10,000 for three years and $15,000 for three years, the Engineering Foundation, established by the United Engineering Society from gifts of Ambrose Swasey and others, has aided in establishing the National Research Council and in supporting its division of engineering; financed an investigation of fatigue phenomena of metals, now in progress, in which a leading industrial corporation has recently joined, making a large financial contribution; and also has financed a hydraulic research which resulted in an improved weir with a straight-line formula. It has participated in a study of spray camouflage of ships, supported a study in the mental hygiene of industry and compiled for National Research Council a classified directory of industrial research laboratories in the United States. The tests of wear of gears, now in progress, have been financed likewise, and it has investigated the practicability of a testing station for large water wheels and other large hydraulic equipment.

Numerous projects that promised valuable results could not be undertaken because of lack of funds, some of these being:

Organization of laboratories to conduct researches in problems common to many industries

Establishment of research laboratories and institutes

Training men of high scientific and business ability for introduction and operation of better methods of production

Collection, classification, condensation and dissemination of records of research results

Research in characteristics of gas mixtures in relation to liquefaction and separation of gases for industrial purposes

Determination of facts on which to base design of internal-combustion engines for vehicles, ships and stationary powerplants

Investigation of heat transfer

Improvement of utilization of all kinds of fuels

Colloidal lubricants and fundamental lubrication principles investigation

Study of bearing alloys.

Study of laws of crystallization of metals, atomic structure and other problems

Prevention of corrosion of ferrous metals

Researches in metal cutting, drawing and stamping

Experimental study of stress distribution in curved and perforated plates and in machine members

Investigation of failures of materials in structures and machines

Refractories and other ceramic products used in engineering industries

Further information about Engineering Foundation can be had by addressing Alfred D. Flinn, secretary, 29 West 39th Street, New York City. Charles F. Rand, 71 Broadway, New York City, is the chairman of the organization.

PERSONAL NOTES OF THE MEMBERS

Frederick Alberty is no longer mechanical supervisor of the Master Trucks, Inc., Chicago, but has taken a position as mechanical supervisor and chief inspector of the Gary Motor Truck Co., Gary, Ind.

Carroll M. Aument has severed his connection with the Phianna Motors Corporation of New York, Long Island City, N. Y., where he held the position of chief engineer, and has been made general manager of the Wharton Motors Co., Dallas, Tex.

O. C. Berry has resigned as professor of automotive engineering at Purdue University, West Lafayette, Ind., to accept a position in the engineering department of the Hupp Motor Car Corporation, Detroit.

William M. Britton, formerly director of engineering of the Republic Motor Truck Co., Inc., Alma, Mich., is now assistant to the president and chief engineer of the Ruggles Truck Co., also of Alma.

James M. Carples has joined the fiscal department of the Mexican American Corporation, 120 Broadway, New York City. He was formerly eastern manager for H. W. Noble & Co., Rochester, N. Y.

E. P. Chalfant, vice-president and general manager of the Automotive Products Corporation, New York City, has started on a six months' tour through South and Central America to study automotive conditions in that territory.

Donald K. Champaign has joined the efficiency engineering department of the American LaFrance Fire Engine Co., Elmira, N. Y. He was until recently engineer for Champaign Brothers, Ithaca, N. Y.

Harold T. Christensen has become affiliated with the tractor bearings division of the Hyatt Roller Bearing Co., Chicago. He was formerly research engineer for the Emerson-Brantingham Co., Minneapolis.

H. W. Christensen, formerly connected with the Packard Motor Car Co., Detroit, and latterly production manager of the Highway Motors Co., Defiance, Ohio, has become connected with the Golden, Belknap & Swartz Co., 1248 Grand River Avenue, Detroit.

R. A. Cole has severed his connection with the Hayes Wheel Co., Jackson, Mich., where he was employed as efficiency engineer, and has taken a position of a similar nature with the Motor Wheel Corporation, Lansing, Mich.

Rowe H. Cosgrove, who was chief engineer for the Supreme Motors Corporation, Warren, Ohio, has accepted a position as engineer for the Glenwood Engineering Co., East Cleveland, Ohio.

M. E. de Jarny has resigned as general manager of the British Motor Cab Co., London, and is now managing director of the Silva-Plana, Boryslaw, Poland.

S. F. Delvin has accepted a position with the Duplex Truck Co., Lansing, Mich. He was formerly engineer for the Olds Motor Works, of the same city.

S. O. DeOrlow has sailed for the West Indies to establish the truck and tractor industry there for the General Motors Export Co., New York City, of which he is a field representative. He also intends to conduct an extensive research in that territory for the purpose of adapting tractors to foreign fields.

A. S. Duesenberg, formerly assistant engineer of the Duesenberg Motors Corporation, Elizabeth, N. J., now holds a similar position with the Duesenberg Automobile & Motors Co., Indianapolis.

John W. Geiger has been made research assistant in the engineering experiment station, Purdue University, West Lafayette, Ind.

J. E. Gramlich has accepted a position with the Watson Products Corporation, Canastota, N. Y. He was formerly an engineer with the Chase Tractors Corporation, Ltd., Toronto, Ont., Canada.

Arnold J. Halbfass, who was a consulting mechanical engineer at Berne, Switzerland, has opened an office at Bösdorf, Elster, Germany.

C. L. Halladay, formerly assistant to the general manager of the Maxwell Motor Co., Detroit, has been appointed vice-president and general manager of the Jackson Motors Corporation, Jackson, Mich.

M. W. Hanks has been made president of the Hankscraft Co., Madison, Wis.

Carl F. Heineman has become engineer for the Simplicity Motors Co., Seattle, Wash. He previously held a similar position with the Davis Car Co., also of Seattle.

John O. Heinze, who until recently was general manager and chief engineer for the Traction Engine Co., Boyne City, Mich., has removed to Lakeland, Fla.

Ferdinand G. Henry, formerly chief engineer with the George White Co., Jersey City, N. J., has entered the employ of Bibbins-Fillette, Inc., 533 North 11th Street, Philadelphia, as mechanical engineer.

Duncan C. Hooker is no longer electrical engineer for the Johns-Pratt Co., Hartford, Conn.

H. O. C. Isenberg, until recently general manager of factories of the Remington Typewriter Co., Ilion, N. Y., is now connected with the George W. Goethals Co., 40 Wall Street, New York City.

O. H. Jobski has entered the employ of the West Steel Casting Co., Cleveland, as an engineer. He was formerly engineer of the rim and tube division of the Standard Parts Co., also of Cleveland.

A. M. Leoni, chief engineer of the Tioga Mfg. Co., Philadelphia, will in the future have charge of the engineering and production work of the Steinmetz Electric Motor Car Corporation, Baltimore, which has purchased the business of the Tioga company.

O. P. Liebreich is at present a designer with the Bijur Motor Appliance Co., Hoboken, N. J. During the war he was second lieutenant in the Field Artillery Division, located at Camp Taylor, Ky.

Douglas F. Linsley has accepted a position as an engineer with C. H. Wills & Co., Marysville, Mich.

George R. Ludwig has been made sales manager of the Buffalo district for the V. A. Longaker Co., Indianapolis.

G. Harold McNulty, formerly secretary and treasurer of the McNulty Co., Big Rapids, Mich., is now employed as a salesman by the Duesenberg Automobile & Motors Co., Indianapolis.

George B. Mitchell is now assistant manager of sales of the Jones & Laughlin Steel Co., Pittsburgh.

J. A. V. Mongiardino has been appointed manager of the Mexican branch of Chipman, Ltd., 10 Bridge Street, New York City. He was previously special traveler in foreign countries for the same organization.

H. J. Moran is now chief engineer and factory manager for the Abbot-Downing Co., Concord, N. H. He was until recently electrical engineer with the International Motor Co., New York City.

Thomas T. Mott is proprietor and general manager of the Motor Sales Co., 110 South Second Street, Clarksburg, W. Va., heretofore the Chalmers-Marmon Sales Co., at the same address.

H. C. Mougey holds the position of control chemist of the General Motors Research Corporation, Dayton, Ohio, successor to the Dayton-Wright Division of the General Motors Corporation, Dayton, Ohio.

John M. Nickelsen has been made assistant professor of mechanical engineering in charge of automobile design work at the University of Michigan, Ann Arbor, Mich.

J. George Oetzel has accepted a position as engineer with the Fairbanks-Morse Co., Beloit, Wis.

Milton D. Pattullo, formerly draftsman for the Monarch Tractor Co., Watertown, Wis., has been made salesman for the Brandt Mfg. Co., Minneapolis.

Frederick Pearce, who was employed as checker and assistant chief draftsman by the Packard Motor Car Co., Detroit, Mich., has accepted a position as checker for the H. H. Franklin Mfg. Co., Syracuse, N. Y.

Benjamin S. Pfeiffer has opened an office in the First National Bank Building, Chicago, for the practice of consulting engineering, specializing in automotive work. He was previously associated with the Page Co., Chicago.

William J. Quinn has resigned as assistant engineer in charge of the experimental section of the Motor Transport Corps, Bureau of Standards, Washington, and is now superintendent of service with the Murray-Van Sicklen Co., Chicago.

J. Howard Rees is president of the Rees Motor Co., recently incorporated in Columbus, Ohio, to build a high-grade light car which he has designed.

Roswell M. Rennie, formerly superintendent of machinery department, University of Illinois, Urbana, Ill., has recently been made assistant manager of Pink & Co., Cairo, Ill.

M. R. Riddell is now assistant to the director of the Engineering Experiment Station and assistant professor of aeronautic engineering at the University of Illinois, Urbana, Ill. He previously held the position of chief engineer of the Canadian Aeroplanes, Ltd., Toronto, and when that firm ceased operations engaged in private consulting engineering work.

E. H. Ruck has accepted a position with the Mobile Tractor Co., Mobile, Ala. He previously was chief engineer of the Automotive Corporation, Toledo, Ohio.

Adolph P. C. Schramm has opened an office for the practice of consulting engineering at 601 West 177th Street, New York City. He was formerly vice-president and treasurer of the Schramm & Bursch Mfg. Co., 416 Broadway, New York City.

Harry A. Schwartz has been made manager of research of the National Malleable Castings Co., Cleveland. He was previously assistant to the chief engineer of the Defiance Machine Works, Defiance, Ohio.

F. C. Seeger, representative of the Doehler Die-Casting Co., Brooklyn, N. Y., has been transferred from the Detroit office of the company to the Pacific Coast.

Harold B. Sweet, who held the position of assistant to the manager of the autoped division of the American Ever Ready Works, Long Island City, N. Y., has taken a position with the Splitdorf Electrical Co., 98 Warren Street, Newark, N. J.

G. Waine Thomas is now with the Racine Engineering Co., 105 Badger Building, Racine, Wis., having terminated his connection with the ordnance engineering department of the Holt Mfg. Co., Peoria, Ill., where he was an automotive layout draftsman.

B. F. Tillson, assistant superintendent of the New Jersey Zinc Co., Franklin, N. J., was reelected a director of the National Safety Council for a term of three years at its annual meeting in September.

Walter A. Toepel has resigned as engineer in charge of the experimental laboratory of the Splitdorf Electrical Co., Newark, N. J., and has been made an instructor in the Stewart Automobile School, Broadway and Fifty-seventh Street, New York City.

Lewis G. Vogel, formerly advertising engineer for Lewis G. Vogel Co., Detroit, has taken a position as advertising manager for *American Motorist*, 508 Riggs Building, Washington.

William J. Walker has become assistant chief engineer for the Menominee Motor Truck Co. of Wisconsin, Clintonville, Wis. He was until recently a draftsman of the Southern Motor Mfg. Association, Houston, Tex.

Joseph L. White, formerly tester for Robert S. Taylor, Seattle, Wash., has become affiliated with the L. D. Allen Co., Stockton, Cal.

Charles L. Williams has been transferred from the Samson Tractor Co., Division of the General Motors Corporation, Janesville, Wis., to the Jaxon Steel Products Co. Division, Jackson, Mich., where he holds the position of efficiency engineer.

Cyril Wilson, formerly layout draftsman for the National Motor Car & Vehicle Corporation, Indianapolis, has accepted a position as mechanical engineer for Altorfer Brothers Co., Peoria, Ill.

Frank R. Wood has resigned as service manager of the H. J. Koehler Motors Corporation, Newark, N. J., to take up duties in the service department of the Atterbury Motor Car Co., Buffalo.

Harold T. Youngren, formerly engineer with the Siemon Tractor Corporation, Buffalo, has accepted a position as designer with the Pierce-Arrow Motor Car Co., also of Buffalo.

Thomas Zimmerman is now chief engineer of the American Distributing Co., 710 Union Building, Cleveland. He formerly held a similar position in the axle division of the Standard Parts Co., also of that city.

OBITUARIES

HARRY WILFRED DU PUY, president of the Pennsylvania Rubber Co., Jeannette, Pa., died July 4, 1920, aged 39 years. He was born at Allegheny, Pa., Sept. 27, 1880. He was graduated from Yale University with the degree of B.A. in 1903 and later attended Cambridge University, in England. In 1904 he was elected treasurer of the Pennsylvania company and in 1910 also became treasurer of the Polack Tyre Co., which was then being organized. At that time he assumed charge of the manufacture of motor-truck tires, specializing in the design and specifications of tire rims. He was connected also with the design and construction of pneumatic tires in a consulting engineering capacity. He was elected to Member grade in the Society May 22, 1911.

FREDERICK KEARNEY PARKE, who died recently at the age of 50 years, was born at St. Louis, Jan. 10, 1870. His technical education was received at New York University, New York City, and at the Y. M. C. A. Central College, Chicago. In 1904 he was graduated as a certified public accountant from the University of Illinois. During his career he served as secretary of the Board of Supervising Engineers, Chicago; vice-president of the Studebaker Corporation, Detroit; vice-president and general manager of the Universal Motor Truck Co., Detroit; manager for Gunn, Richards & Co., production engineers, New York City, and president of the Olympian Motors Co., Pontiac, Mich. As secretary of the Board of Supervising Engineers of Chicago, from 1907 to 1909, he wrote three volumes on Street Railway Engineering and Accounting and later carried on a general consulting practice in engineering and accounting. He was an honorary member of the American Railway Accounting Officers' Association and was elected to Member grade in the Society April 17, 1917.

CORWIN VAN HUSAN, aged 24 years, formerly of the Air Service, was killed in an automobile accident, Aug. 30, 1920. He was born Feb. 8, 1896, at Detroit, and received his preliminary and technical education in the local high school and through private tutoring in engineering. From 1914 to 1915 he studied aeronautics, owning and operating a flying boat. While secretary and treasurer of the General Aeroplane Co., from 1915 to 1917, he carried on experiments and was partly responsible for the design of successful flying boats. In November, 1917, he entered the Air Service and taught airplane mechanics to airplane instructors. He was elected to Junior member grade in the Society Dec. 23, 1918.

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Sept. 10 and Oct. 10, 1920. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate Member; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ABELL, HARRY C. (A) plant engineer, Laminated Shim Co., Inc., New York City, (mail) 1009 Main Street, *Asbury Park, N. J.*

ADLER, WILLIAM KARL (A) assistant electrical engineer, International Harvester Co., *Chicago,* (mail) 6028 South Lincoln Street.

AKE, MERLIN E. (M) superintendent of production, Firestone Tire & Rubber Co., *Akron, Ohio.*

APPLE, LYNFORD A. (A) manager, General Motors Corporation, Bloomfield, N. J., (mail) 272 Park Street, *Upper Montclair, N. J.*

ARBUCKLE, SAMUEL F. (M) sales engineer, U. S. Automotive Corporation, *Connersville, Ind.*

ARMSTRONG, J. FRED (A) secretary, Sheldon Axle & Spring Co., *Wilkes-Barre, Pa.*

AUSTIN, W. S. (M) chief engineer, Symington, Hoffman & Co., Maryland Trust Building, *Baltimore, Md.*

BAKER, L. LESTER (J) chief draftsman King Motor Car Co., *Detroit,* (mail) 351½ Van Dyke Avenue.

BEECK, JOSEPH (A) mechanical engineer, property division, Air Service, Munitions Building, 19th and B Streets, Northwest, *Washington.*

BENNETT, HUBERT D. (J) advertising department, Willys-Overland, Inc., *Toledo, Ohio,* (mail) The Miltimore.

BERNHART, EDWIN L. (A) engineer, Northway Motors Corporation, Natick, Mass., (mail) 2½ Raymond Street, *Framingham, Mass.*

BIRCHARD, E. R. (A) technical engineer, Republic Motor Car Co. of Canada, 522 Yonge Street, *Toronto, Ont., Canada.*

BIRD, HARLAN W. (E S) student in mechanical engineering, Armour Institute of Technology, *Chicago,* (mail) 5441 Kenmore Avenue.

BLESSING, M. A. (A) manager of sales, Jones & Laughlin Steel Co., 440 West Lake Street, *Chicago.*

BRASIER, HARRY E. (A) service manager, Willys-Overland, Ltd., West Toronto, Canada, (mail) 337 Dovercourt Road, *Toronto, Ont., Canada.*

BURLEY, E. R., JR. (M) chief engineer and production manager, Available Truck Co., Chicago, (mail) 327 South Scoville Avenue, *Oak Park, Ill.*

CHANDLER, ROBERT A. (A) 265 West 38th Street, *New York City.*

DALRYMPLE, FITZWILLIAM, JR. (A) student, Century Plainfield Tire Co., Plainfield, N. J., (mail) Beauchamp Place, *New Rochelle, N. Y.*

DOBLE, ABNER (M) chief engineer, Standard Gas Engine Co., Dennison and King Streets, *Oakland, Cal.*

DOHNER, BURT E. (A) secretary and treasurer, Ohio Metal Products Co., 35 Bates Street, *Dayton, Ohio.*

DOHNER, JOHN H. (A) president and general manager, Ohio Metal Products Co., 35 Bates Street, *Dayton, Ohio.*

FARMER, A. M. (A) industrial engineer, L. W. Estes, Inc., Chicago, (mail) Engman Matthews Range Co., *South Bend, Ind.*

FREELAND, HILTON G. (M) metallurgist, Hoover Steel Ball Co., *Ann Arbor, Mich.,* (mail) 804 Dewey Street.

FRITCH, GILES MORTON (M) assistant superintendent and technical supervisor American Brass Co., *Kenosha, Wis.*

GALLEY, CHARLES E. (J) repairman, Packard Motor Car Co., *Detroit,* (mail) Room 739, Y. M. C. A.

GAYLORD, LISLE HOWARD (A) chief draftsman, axle process engineering division, General Motors Corporation, Detroit, (mail) 2530 66th Avenue, *Oakland, Cal.*

GRASETT, D. BLIGH (A) manager, automobile division, Crane Packing Co., *Chicago,* (mail) 4736 Beacon Street.

GROSS, WILLIAM N. (E S) marine engine and boiler draftsman, New York Navy Yard, (mail) 914 Lafayette Avenue, *Brooklyn, N. Y.*

GROVE, H. E. (A) truck sales export department, International Motor Co., *New York City,* (mail) P. O. Box 71, Station W.

GUILD, THOMAS A. (A) manager of sales, Westinghouse Union Battery Co., *Swissvale, Pa.*

HALE, ROY F. (J) salvaging engineer, Holt Mfg. Co., (mail) 429 West Nebraska Avenue, *Peoria, Ill.*

HALL, DONALD A. (J) aeronautical draftsman and checker, Curtiss Engineering Corporation, Garden City, N. Y. (mail) 37 Lent Avenue, *Hempstead, N. Y.*

HANSEN, MILES G. (M) superintendent, Willys Corporation, *Toledo, Ohio,* (mail) 579 Mulberry Street.

HARTRICK, CHARLES E. (M) experimental research engineer, Ford Motor Co., *Detroit,* (mail) 218 Hague Avenue.

HAWES, GEORGE P., JR. (S M) *Camp Holabird, Md.*

HEATH, LEWIS H. (M) general manager, Litscher Lite Corporation, *Grand Rapids, Mich.,* (mail) P. O. Box 364.

HEINEMANN, J. A. (M) chief engineer, Dragon Motors Corporation, 3900 North Claremont Avenue, *Chicago.*

HERR, JAMES H. (M) aeronautical engineer, engineering division, Air Service, McCook Field, *Dayton, Ohio,* (mail) 44 Locust Street.

HIGINBOTHAM, ARTHUR O. (A) chief engineer, Charles B. Foster & Co., 116 Exchange Street, *Worcester, Mass.*

HORNER, FREDERICK C. (A) transportation engineer, Packard Motor Car Co., *New York City,* (mail) 181 East 80th Street.

HOWARD, WILLIAM D. M. (A) engineer, Boston Auto-Gage Co., Boston, (mail) 45 Islington Road, *Auburndale, Mass.*

HOWLETT, LIEUT. JOHN A. (A) Camp Mormoyle, *San Antonio, Tex.*

HUBACH, GUSTAVE (A) mold engineer, Fisk Rubber Co., Chicopee Falls, Mass., (mail) 121 Sherman Avenue, *Springfield, Mass.*

JOHNSTON, HOWARD A. (A) manager, sales promotion department, Standard Steel & Bearings, Inc., 5001 Lancaster Avenue, *Philadelphia.*

JONES, EDWIN OLNEY (A) sales engineer, Federal Bearing & Bushing Corporation, 362 Trombley Avenue, *Detroit.*

JONES, G. DOUGLAS (M) agricultural engineer, Cleveland Tractor Co., *Cleveland.*

KELLY, GEORGE B. (J) draftsman, Acme Motor Truck Co., *Cadillac, Mich.*

KING, CHARLES D. (J) chief engineer, Killington Machine Co., Syracuse, N. Y., (mail) 15 Charlotte Street, *Baldwinsville, N. Y.*

LANNING, JOHN G. (M) assistant vice-president, Detroit Lubricator Co., *Detroit,* (mail) 341 Putnam Avenue.

LAURENT, M. P. (J) designing engineer, Fairbanks, Morse & Co., *Three Rivers, Mich.,* (mail) 206 Rock River Avenue.

LA VISTA, FRANK W. (A) assembly superintendent, L. W. F. Engineering Co., *College Point, N. Y.,* (mail) 16th Street and Eighth Avenue.

LIVERMORE, WILLIAM T. (J) jig and fixture trouble man making shop investigations for engineering department, Northway Motor Co., Natick, Mass., (mail) 62 Thorndike Street, *Lawrence, Mass.*

LOHR, CHARLES E. (M) production manager, Chandler Motor Car Co., *Cleveland.*

MCDONALD, C. R. (A) sales manager, Gibson Co., *Indianapolis,* (mail) 321 East Falls Creek Boulevard.

MACKENZIE ROY J. (A) president, Buffalo Pressed Steel Co., 778 Kensington Avenue, *Buffalo.*

MANBY, BERTRAM C. (A) *Taos, N. M.*

MIDDLETON, W. IRVING (M) electrical engineer, Simplex Wire & Cable Co., 201 Devonshire Street, *Boston.*

MILES, CHARLES (M) experimental engineer, International Harvester Co., *Akron, Ohio.*

MILLER, ALFRED H. (M) secretary, treasurer and engineer, Wright Roller Bearing Co., *Philadelphia,* (mail) 1420 Chestnut Street.

MOHL, DONALD J. (J) draftsman, Acme Motor Truck Co., 442 Washington Street, *Cadillac, Mich.*

MOONEY, JAMES DAVID (M) general manager, Remy Electric Division, General Motors Corporation, *Anderson, Ind.*

MOORE, GEORGE T. (A) sales director, Wisconsin Parts Co., *Oshkosh, Wis.,* (mail) 27 Evaline Street.

MORGAN, E. K. (M) general superintendent, Rockford Drilling Machine Co., *Rockford, Ill.,* (mail) 520 Frost Court.

MORSE, ALAN LUTHER (E S) Massachusetts Institute of Technology, Cambridge, Mass., (mail) 90 Somerset Street, *Belmont, Mass.*

NEIL, EDMUND B. (M) mechanical engineer, sales engineering department, Pierce-Arrow Motor Car Co., *Buffalo,* (mail) 115 St. James Place.

NICHTA, JOHN J. (J) assistant engineer and designer, Aluminum Manufactures, Inc., *Cleveland,* (mail) 4342 Martin Avenue.

OKEY, PERRY (M) proprietor, Okey Mfg. Co., Naghten and Water Streets, *Columbus, Ohio.*

OLSON, CLARENCE T. (J) service draftsman, U. S. Ball Bearing Mfg. Co., *Chicago,* (mail) 1421 Balmoral Avenue.

REYNOLDS, CLEARTON H. (S M) airplane pilot and engineer, Air Service, *Langley Field, Va.*

RICHARDSON, IRVIN FOGG, (A) engineer, automobile department, Vacuum Oil Co., Boston, (mail) 129 Franklin Street, *Allston, Mass.*

RODWAY, G. H. (M) chief engineer, Wolseley Motors, Ltd., *Birmingham, England,* (mail) The Manse, Birmingham Road, Wylde Green.

ROGER, HARRY E. (A) sales inspection engineer, Timken-Detroit Axle Co., *Detroit,* (mail) 1403 Conway Building.

SEMPLE, CHARLES C. (M) chief engineer, Rochester Motors Corporation, *Rochester, N. Y.,* (mail) 205 Bryan Street.

SHAW, A. D. (A) engineering salesman, S K F Industries, Inc., New York City, (mail) 1624 Real Estate Trust Building, *Philadelphia.*

SIMPSON, CARL W. (M) metallurgist, American Axle Division, Standard Parts Co., *Cleveland,* (mail) 10403 Colonial Avenue.

STEVENSON, GEORGE R. (J) chief engineer, Stevenson Gear Co., *Indianapolis,* (mail) 310 North Illinois Street.

STORTZ, ROBERT (M) assistant to chief engineer, Nash Motors Co., *Kenosha, Wis.,* (mail) 659 Elmhurst Avenue.

SWARTWOUT, F. B. (J) 1876 Knowles Street, *Cleveland.*

TAYLOR, B. G. (A) Banksia Motor Co., Ltd., Railway Crescent, *Arncliffe, New South Wales.*

THEARLE, ERNEST LATHROP (E S) student, 123 Linden Avenue, *Ithaca, N. Y.*

TIMIAN, HAL H. (J) experimental engineer, Haynes Automobile Co., *Kokomo, Ind.,* (mail) 621 East Walnut Street.

TOWNSEND, H. A. (A) educational director, Newark Y. M. C. A. Auto School, Newark, N. J., (mail) 101 Webster Street, *Malone, N. Y.*

TUNISON, M. C. (M) constructor and mechanical engineer, Tunison Products Co., 317 Thayer Building, *Oakland, Cal.*

WADE, JUNIUS S. (J) mechanical engineer, Wade & Wait, *Augusta, Ark.*

WALKER, R. L. (A) production manager, Sewell Cushion Wheel Co., 1296 Gratiot Avenue, *Detroit.*

WALLACE, WILLIAM H. (A) sales engineer, Perfection Spring Co., 65th Street and Central Avenue, Cleveland, (mail) 2019 Brown Road, *Lakewood, Ohio.*

WALKER, WILLIAM J. (J) draftsman, Southern Motor Mfg. Association, Houston, Tex., (mail) P. O. Box 273, *Clintonville, Wis.*

WILSON, O. STERLING (J) assistant chief draftsman, Glenn L. Martin Co., Cleveland, (mail) 1870 Nela Avenue, *East Cleveland, Ohio.*

WILSON, ROBERT W. (J) Vulcan Motor Axle Co., 75 Conant Avenue, *Detroit.*

YANSS, GEORGE W. (J) mechanical engineer, Spicer Mfg. Corporation, *Pottstown, Pa.*, (mail) 237 High Street.

ZICKEL, ABRAHAM (J) assistant manager of sales, R. E. Peoples & Co., *Newark, N. J.*, (mail) 152 Bergen Street.

ZIMMERMANN, WALTER V. (A) service manager, Olds Motor Works, *Lansing, Mich.*, (mail) 217 South Pine Street.

Applicants *for* Membership

The applications for membership received between Sept. 20 and Oct. 15, 1920, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ABRAMOVICS, HARRY, draftsman and tool designer, Noma Motor Corporation, *New York City.*

ACKLIN, J. M., vice-president and manager, Acklin Stamping Co., *Toledo, Ohio.*

ANDO, CHIJO, designer and production manager, Nakashima Aircraft Works, *Ota, Gunmaken, Japan.*

BEALS, J. C., service representative, Francis C. Davidson, Inc., *Los Angeles, Cal.*

BLACK, SAMUEL C., production engineer, Briscoe Motor Corporation, *Jackson, Mich.*

BORGEN, CARL K., service superintendent, Standard Steel Automotive Corporation, *Los Angeles, Cal.*

BORNSTEIN, JOSEPH, chief engineer and works manager, American Metal Parts Corporation, *Boston.*

BRACKENRIDGE, J. H., chief engineer clerk, Cleveland Tractor Co., *Cleveland.*

BREER, CARL, assistant chief engineer, Willys Corporation, *Elizabeth, N. J.*

BRENNAN, C. H., sales manager, Jefferson Forge Products Co., *Detroit.*

BRENNER, RAYMOND E., engineer, Transport Truck Co., *Alma, Mich.*

BREVAIRE, A. A., chief maintenance engineer, Hare's Motors, Inc., *New York City.*

BROWN, FRANK L., general superintendent, White Motor Co., *Cleveland.*

BURCH, WILLIAM H., assistant chief engineer, Elgin Motor Car Corporation, *Argo, Ill.*

CARPENTER, MAJOR WILLIAM T., Coast Artillery Corps, c/o Holt Mfg. Co., *Stockton, Cal.*

CHESTNUT, FRED H., transportation engineer, White Co., *San Francisco.*

COLLINS, F. ALTON, JR., manager, Auburn Ball Bearing Co., *Rochester, N. Y.*

COMEY, H. C., factory manager, Texas Motor Car Co., *Fort Worth, Tex.*

DAVIDSON, E. Y., JR., illuminating engineer, Macbeth-Evans Glass Co., *Pittsburgh.*

DAVIS, HOWARD LA MONTE, sales engineer, Connecticut Telephone & Electric Co., *Meriden, Conn.*

DEAN, KENNETH G., president, Lakewood Screw Machine Products Co., *Cleveland.*

DEIMEL, ALBERT H., experimental engineer, Chrobeltic Tool Co., *Michigan City, Ind.*

DOUTHITT, H. N., vice-president and general manager, Detroit Transmission Co., *Detroit.*

DRYDEN, J. L., general manager and treasurer, Long Mfg. Co., *Detroit.*

FRAME, C. C., chief transportation engineer, Service Motor Truck Co., *Wabash, Ind.*

GERDTS, CHARLES, sheet metal layout man, Chevrolet Motor Co., *New York City.*

GILMAN, NORMAN H., general manager and chief engineer, Allison Experimental Co., *Indianapolis.*

GILMORE, ROGER J., president, Hare's Motors of New England, *Boston.*

GILSON, A., mechanical engineer, Packard Motor Car Co., *Detroit.*

GRADY, F. HOWARD, draftsman, Hyatt Roller Bearing Co., *Detroit.*

GRISWOLD, WALTER R., engineer, Packard Motor Car Co., *Detroit.*

HEGENAUER, CHARLES J., mechanical draftsman, Chevrolet Motor Co., *New York City.*

HENDERSON, WILLIAM WALTER, cost estimator and planner, Oakes Co., *Indianapolis, Ind.*

HENRY, JOHN J., experimental work, Bethlehem Motors Corporation, *Pottstown, Pa.*

HIGGINS, H. A., chief engineer, Long Mfg. Co., *Detroit.*

HIROKI, TAKEO, J., American Steel Co., *Waynesburg, Pa.*

HOCKENBERGER, G. C., engineer, 212 Union Avenue, *Bridgeport, Conn.*

HUNT, ERNEST C., JR., assistant superintendent, Morse Chain Co., *Ithaca, N. Y.*

HUNTER, HARRY M. L., salesman, Cincinnati branch, Jones & Laughlin Steel Co., *Pittsburgh.*

JEPSON, WILLIAM A., salesman, Robertson Lubricants Co., *Philadelphia.*

KORN, ALEXANDER A., chief engineer, Morand Cushion Wheel Co., *Chicago.*

LA CHANCE, ARTHUR T., production dispatcher, Lincoln Motor Co., *Detroit.*

LAKE, L. C., shop foreman, Ralph H. Butler, *San Francisco.*

LIEBERMAN, A. W., designer, Goodyear Tire & Rubber Co., *Akron, Ohio.*

LOVEN, OTTO H., designer, G. Drouve Co., *Bridgeport, Conn.*

MCCLAIN, HARRY O., chief engineer and production manager, American Truck & Trailer Corporation, *Kankakee, Ill.*

MCCREERY, H. L., chief engineer, Standard Welding Co., *Cleveland.*

MCILHINEY, DONALD W., editorial staff, Class Journal Co., *New York City.*

MCKEE, WILLIAM J., assistant to president, Osgood Bradley Car Co., *Worcester, Mass.*

MCNAIR, JAMES TAYLOR, assistant service manager, Detroit Cadillac Motor Car Co., *New York City.*

MALOON, EARL B., draftsman, C. L. Best Gas Traction Co., *San Leandro, Cal.*

MAURER, C. N., mechanical engineer, Wisconsin Highway Commission, *Madison, Wis.*

MERANDA, WILLIAM O., chief draftsman, Hoosier Auto Parts Co., *Muncie, Ind.*

MORAND, LESTER, mechanical engineer, Morand Cushion Wheel Co., *Chicago.*

MOWRY, ROLLIN I., factory manager, Dyneto Electric Corporation, *Syracuse, N. Y.*

NASH, CARLETON BIRTLEY, assistant engineer, Maccar Truck Co., *Scranton, Pa.*

NEWTON, W. B., mechanical draftsman, Holt Mfg. Co., *Stockton, Cal.*

NICHOLS, W. W., mechanical engineer, D. P. Brown & Co., *Detroit.*

PETERS, JOHN F. P., superintendent, Northway Motors Corporation, *Natick, Mass.*

PLOPPER, BENJAMIN C., cost and production manager, Topp-Stewart Tractor Co., *Clintonville, Wis.*

POLHEMUS, DONALD W., draftsman, Class Journal Co., *New York City.*

PYLER, O. G., assistant chief engineer, Cleveland Automobile Co., *Cleveland.*

REED, RODMAN S., chief engineer, Brockway Motor Truck Co., *Cortland, N. Y.*

REINHART, FRANK W., sales engineer, American Oil Corporation, *Jackson, Mich.*

RODE, EDWARD W. P., service manager, Buffalo Sterling Co., Inc., *Buffalo.*

RUSSOM, DOUGLAS A., test engineer, International Harvester Co., *Chicago.*

SAWYER, WILFRED D., assistant engineer, Baker Steam Motor Car & Mfg. Co., *Pueblo, Col.*

STANTON, RICHARD F., engineer in charge of planning department, Pratt & Whitney Co., *Hartford, Conn.*

STOLTING, FRED J., draftsman, Holt Mfg. Co., *Stockton, Cal.*

STONE, FRANK J., branch manager, Electric Storage Battery Co. of Philadelphia, *Boston.*

STUDNICKA, JOSEPH, tool and machine designer, Dodge Bros., *Detroit.*

THOMPSON, JOHN F., manager, technical department, International Nickel Co., *New York City.*

VANNEMAN, JOHN A., engineer, Eisemann Magneto Corporation, *Brooklyn, N. Y.*

WAGNER, PARKER, special technical representative, Hare's Motors Co. of New England, *Boston.*

WALTER, C. C., service manager, Standard Steel Car Co., *Pittsburgh.*

WARNER, W. M., manager, parts department, Cadillac Motor Car Co., *Detroit.*

WHEATLEY, WILLIAM BALLANTINE, student, Pratt Institute, *Brooklyn, N. Y.*